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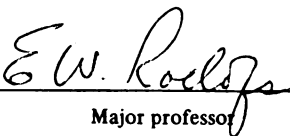
Some Aspects of the Population Ecology of
the Smallmouth Bass in a Small Michigan Stream

presented by

Thomas C. Dewberry

has been accepted towards fulfillment
of the requirements for

Master degree in Fisheries & Wildlife


Major professor

Date _____



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SOME ASPECTS OF THE POPULATION ECOLOGY
OF THE SMALLMOUTH BASS IN A SMALL
MICHIGAN STREAM

By

Thomas C. Dewberry

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Fisheries and Wildlife

1978

6108804

ABSTRACT

SOME ASPECTS OF THE POPULATION ECOLOGY OF THE SMALLMOUTH BASS IN A SMALL MICHIGAN STREAM

By

Thomas C. Dewberry

The population of large smallmouth bass appeared to vary greatly throughout the year in Spring Brook. The most plausible explanation was that the fish were migratory.

Mark-and-recapture electrofishing inventories were conducted in April, June, and September. A weir with two-way fish traps was maintained from April into September.

The data indicated the large smallmouth bass were not migratory. They did move considerably during the year but movement was generally limited to about 1 km. Analysis of their habitat requirements provided an explanation for the movement.

An investigation of the geology and hydrology of the drainage basin provided an explanation for the distribution of smallmouth bass in Spring Brook.

The size of crayfish eaten by the rockbass and smallmouth bass, combined with field observations, suggested that Age-I and II smallmouth bass fed primarily in riffles; while the rockbass predominantly fed in the vegetational areas along the stream margin.

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ACKNOWLEDGMENTS

I wish to express my personal gratitude to Dr. Eugene Roelofs, under whose guidance this study and degree were undertaken, and to my graduate committee, Dr. Grahame Larson, Dr. Niles Kevern, and Dr. Ray White whose suggestions and criticisms were invaluable in the preparation of the manuscript.

I am also grateful to all my colleagues , too numerous to name at this point, for their assistance throughout the study.

Special thanks are also extended to the Michigan Department of Natural Resources, especially Mr. David Havens, for designing and building the weir.

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INTRODUCTION

In Michigan, warm-water streams have received little attention from biologists. This situation seems perplexing since the top predator in these systems is one of the most sought-after game fish in North America, the smallmouth bass. One would expect south-central Michigan streams to rank among the best smallmouth bass streams in the country because southern Michigan is located near the center of the smallmouth bass's range.

Fifty years ago, the Grand, Kalamazoo, and St. Joseph Rivers and their tributaries were nationally renowned smallmouth bass streams (Figure 1). Since that time the watersheds have been highly developed. Industrial, urban, and agricultural development proceeded and the streams lost groundwater input when channelized, which destroyed much smallmouth bass habitat; erosion increased stream turbidity; and more effluent and fertilizers entered the streams. Many of these warm-water streams shifted from an autotrophic state, augmented by imported energy from the watershed to an import-export regime where large influxes of organic matter outweighed production in the stream itself (Vannote 1963). As a result, the smallmouth bass populations in the southern Michigan area have been greatly reduced.

Spring Brook, a minor third order (Horton 1945) tributary of the Grand River, is unusual. It is among the least perturbed

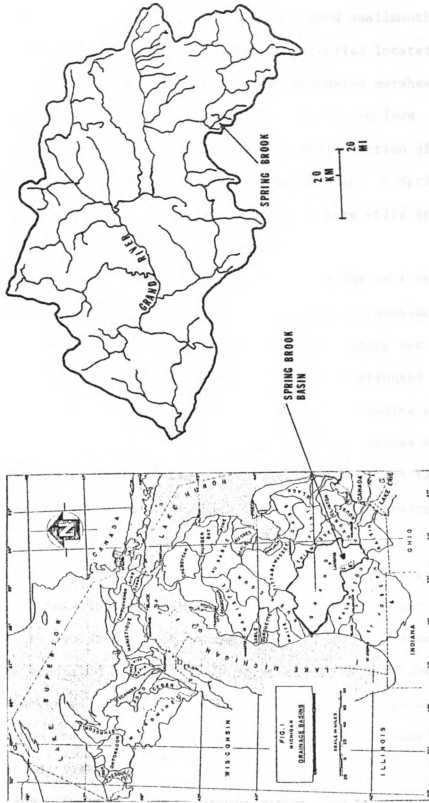


Figure 1. Michigan river basins and the location of Spring Brook.

streams in south-central Michigan and is a good smallmouth bass stream. There are no towns, villages, or factories located within the drainage basin above the study area. Extensive marshes in the upper two-thirds of the basin buffer the stream from agricultural and urban activities. Only a small section of the stream has been channelized. The streams adjacent to Spring Brook have been managed as marginal trout streams while Spring Brook has not.

The study area was selected because it is the section of Spring Brook which contained the largest number of smallmouth bass and has provided me with good smallmouth bass fishing for 15 years. The stream reach can be sampled effectively with standard gear. There were no pools too deep to sample by electrofishing nor was the channel blocked by log jams. Adjacent stream reaches harbored fewer but larger bass. In these sections, I have caught bass up to 3.1 kg. In the study area, which receives little fishing, the largest smallmouth bass was just under 1.9 kg.

For many years, I have observed that the number of large smallmouth bass in some sections of Spring Brook seemed to vary greatly throughout the year. A preliminary study of the smallmouth bass was conducted during 1976. A large number of bass over 350 mm were observed in the spring. By midsummer, few large bass could be found in the study sections. The possible explanations for this included: 1) fishing mortality, 2) natural mortality, 3) emigration. Fishing mortality was unlikely; few fishermen were observed in the study area. Natural mortality was also unlikely;

smallmouth bass are long-lived. The most plausible explanation for the phenomenon was emigration. A literature review revealed the extent of migrations in smallmouth bass was unknown. Webster (1954), Cleary (1956), Trautman (1957), and Robbins (1975) reported the occurrence of migrations in bass populations. Funk (1957) found that a group of smallmouth bass were mobile, however, the fish were generally immature.

The primary objective of this study was to gain an understanding of the mechanism causing the fluctuation of large smallmouth bass in the study area of Spring Brook. An investigation of the physical aspects of the watershed was also conducted to gain an understanding of the distribution of smallmouth bass in Spring Brook.

STUDY AREA DESCRIPTION

Spring Brook, a minor tributary of the Grand River, rises in a sedge-grass marsh in north-western Jackson County and flows north 29.4 km to its confluence with the Grand River at the town of Eaton Rapids (Figures 1 and 2). The Spring Brook drainage basin was defined as the segment of stream and associated catchment basin upstream from Spicerville Road, the site of a U.S.G.S. partial records station. The drainage area is 147.6 km². The upper half of the basin consists of sand, gravel, and glacial till overlying Saginaw Sandstone. The lower half of the basin is primarily 30-60 m of glacial till overlying bedrock. The dominant land use in the basin is agriculture, although the upper two-thirds of the basin has extensive marshes generally wider than 1 km (Figure 3). The marshes are primarily managed as wildlife habitat and provide an extensive "green belt" for the stream. Mean gradient of the upper two-thirds of Spring Brook is 0.04%. The mean gradient of the lower one-third of the stream, which includes the study area, is 0.85% (4.5 ft/mi).

The study area encompassed 1.95 km of Spring Brook between Bradford and Holmes Roads in Eaton County (Figures 2 and 4). This reach has a moderately well-developed riffle-pool profile and a substrate of predominantly rubble and boulders.

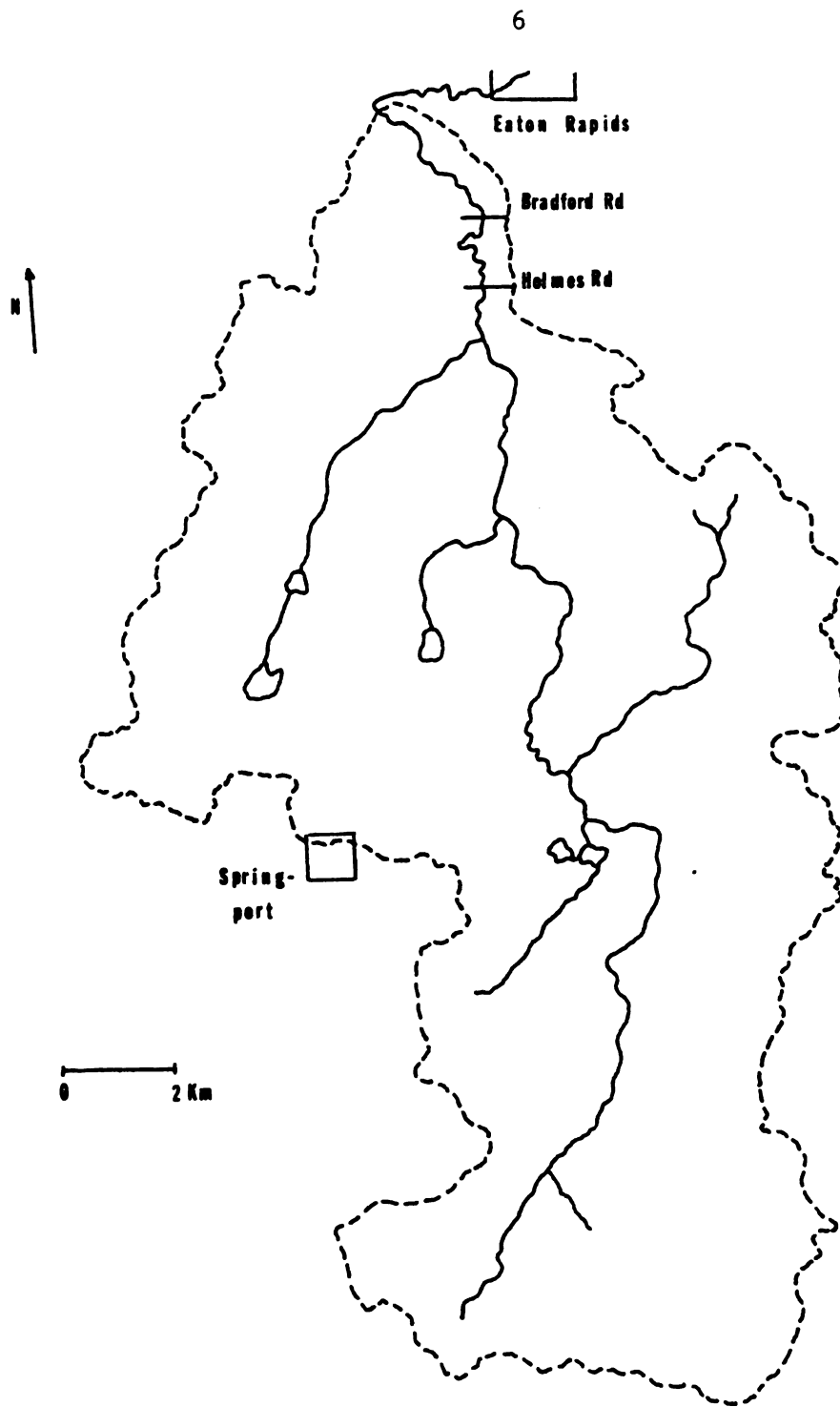


Figure 2. The Spring Brook drainage basin.

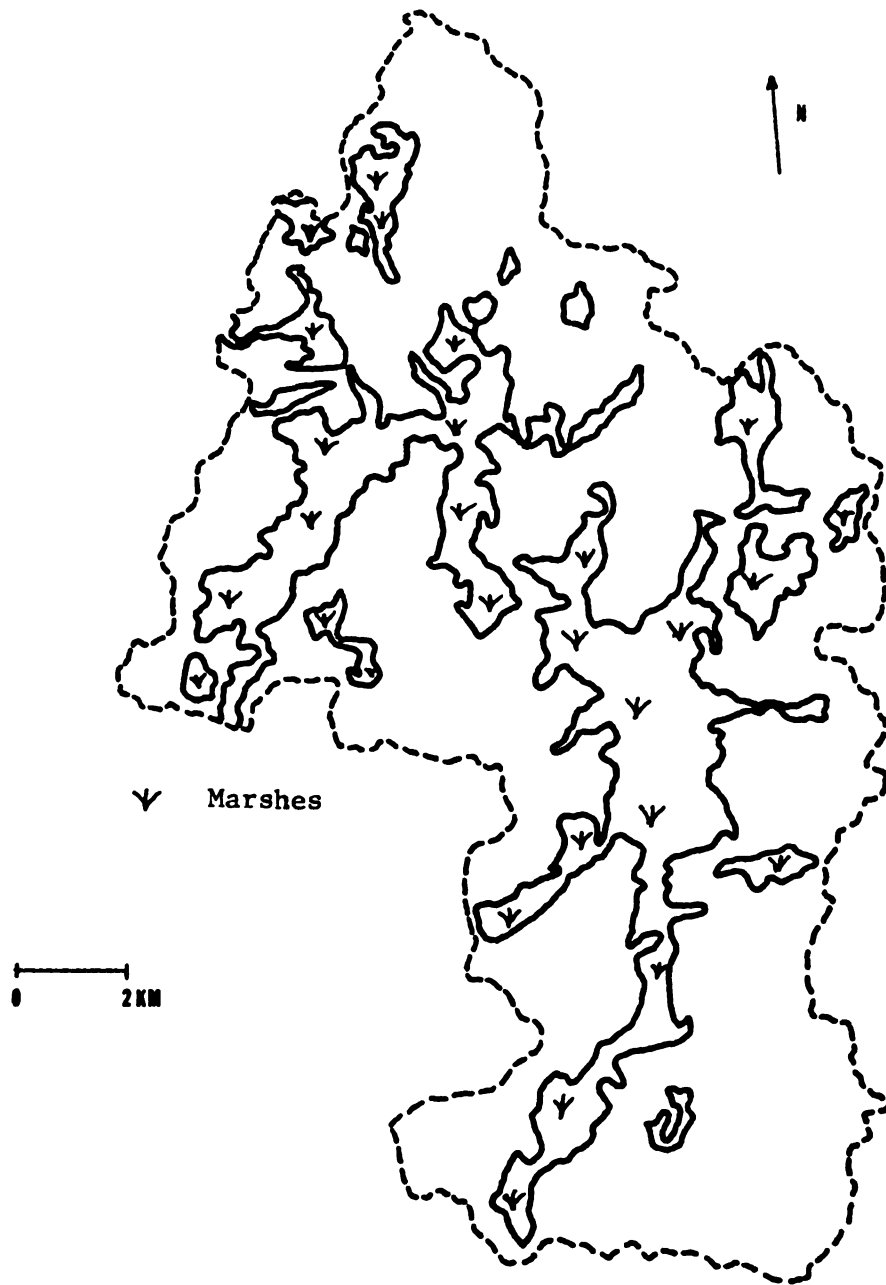


Figure 3. Location of marshes in the Spring Brook basin.

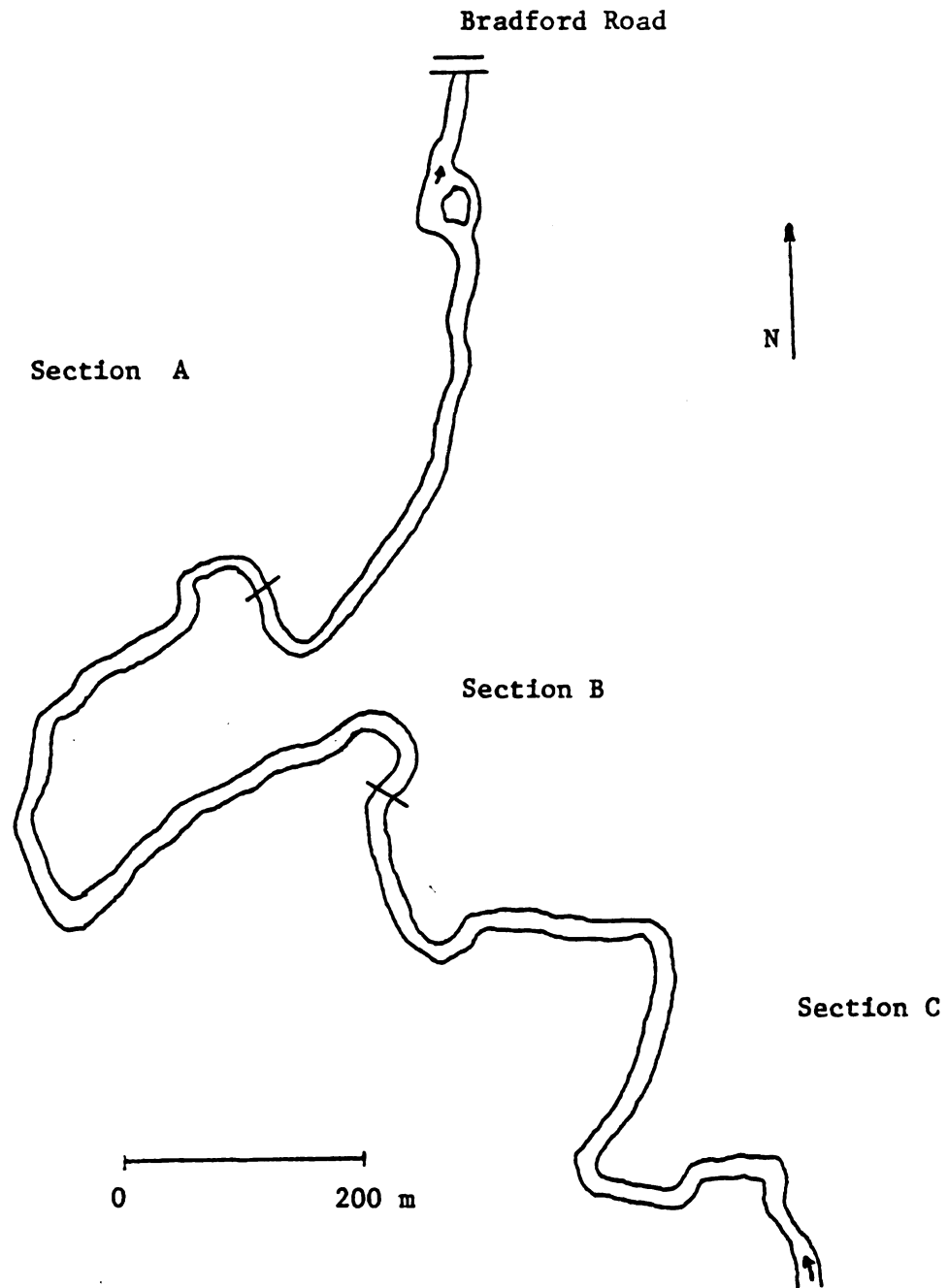


Figure 4. The study area of Spring Brook.

The channel is about 7 m wide with pools about 1 m deep at a base flow of $0.14 \text{ m}^3/\text{sec}$. During the preliminary study, the research area was divided into 3 sections of about equal length (Figure 4). Sections A and C were high gradient sections, principally long shallow riffles. The substrate was mainly rubble and boulders which had armor-plated the stream bed. The pools were not well developed. Section B consisted of several habitats. The upper 30 m was the largest and deepest pool in the study area, the substrate being composed of sand and large boulders. A long shallow, sandy riffle occupied the rest of the upper half of this section. The lower half of section B had a low gradient, deep pools, and slow flow. The substrate in the thalweg was sand in gravel. In adjacent areas extensive silt deposits had formed. A small log jam and overhanging shrubs provided an abundance of cover.

The tree canopy over the study area was 50% closed, 45% partial, and 5% open. The preponderance of canopy cover indicated allochthonous detritus was probably important in the stream's trophic system. Lists of the flora and fauna are given in Appendix I, along with their microhabitat associations and relative abundance throughout the year.

SMALLMOUTH BASS POPULATION

Methods

Estimates of the smallmouth bass population in the study area were made by mark-and recapture electrofishing with calculations by the Bailey Modification of the Petersen Method (Ricker 1958).

$$P = \frac{M (C+1)}{R+1}$$

where P is the population estimate, M is the number of fish marked on the first run, C is the number of marked and unmarked fish captured on the second run. Confidence intervals were calculated for the population estimates according to the procedure outlined by Davis (1964). The 95% confidence intervals were obtained from the tables given in Adams (1951). The bass were partitioned into 3 size groups by the methods outlined by MacFadden (1961) to determine if gross changes in the size distribution took place during the year.

The electrofishing inventories were made in April, June, and September. Care was taken to minimize the movement between the sections. The sections were delimited by shallow riffles. During the April population estimate, block nets were placed in the riffles to minimize movement. A 240-volt AC generator rectified to DC was mounted in a small boat which was towed by a crew member. Three

positive electrodes were attached to 8 m cables. The ground was a piece of copper screen attached to a styrofoam float and towed behind the boat.

The weir and a 2-way fish trap were maintained from April to September 1977. The weir, located about 1 km below the study area, blocked the movement of all bass greater than 155 mm. The trap consisted of two live-boxes each with a funnel in one end, placed so that the funnel of one faced upstream and that of the other downstream.

A creel survey was conducted from late May through September to characterize the angler harvest. On weekdays, the study area was walked morning and evening. On weekends during June and July, the area was walked hourly throughout the daylight hours. The landowners along the stream also provided valuable assistance by notifying me when they saw anglers in the area.

Results and Discussion

Initially, we experienced all the problems Vannote (1963) indicated. Smallmouth bass could avoid recapture by direct-current electrofishing gear. They apparently could escape the margin of an approaching electrical field. If they were attracted, the bass often approached at high speeds and frequently were carried completely through the field. During the first population estimate, the most successful technique consisted of moving quickly between pools, using the element of surprise. The last few meters before a pool, we would move slowly with the electrodes out of the water. If fish were seen ahead of us, an electrode was touched to the water

for about 1 second. The electrodes were simultaneously thrust into the pool and moved very quickly. This appeared to disorient the bass. Later in the season, a more successful technique was to place the electrodes in a line across the stream. The crew would then move slowly upstream manipulating the electrodes slowly.

The electrofishing inventories indicated the number of large bass changed markedly in each section, while in the research area as a whole, there was little change in the population numbers (Figure 5 and Table 1). The assumption of equal catchability for each size group was accepted (Table 2). The population estimates for each section could not be determined independently because of the high mobility between sections. For example, 55.5% of the recaptured fish had changed sections between the first and second runs of the April population estimate. The number of large bass in sections A and C declined from spring to summer. About half of the large bass which disappeared from sections A and C were recaptured in June and September in section B.

The section of stream between the study area and the weir was electrofished during the June population estimate to determine the number of marked fish that had moved downstream of the study area but upstream of the weir. A total of nine marked bass were identified. Located in this section was a large log jam and a hole too deep to adequately electrofish. Angling this section indicated a large number of bass.

The 800-m section above the research area to Holmes Road was electrofished during the September estimate to determine the number of marked fish which had moved above the study area. A total of

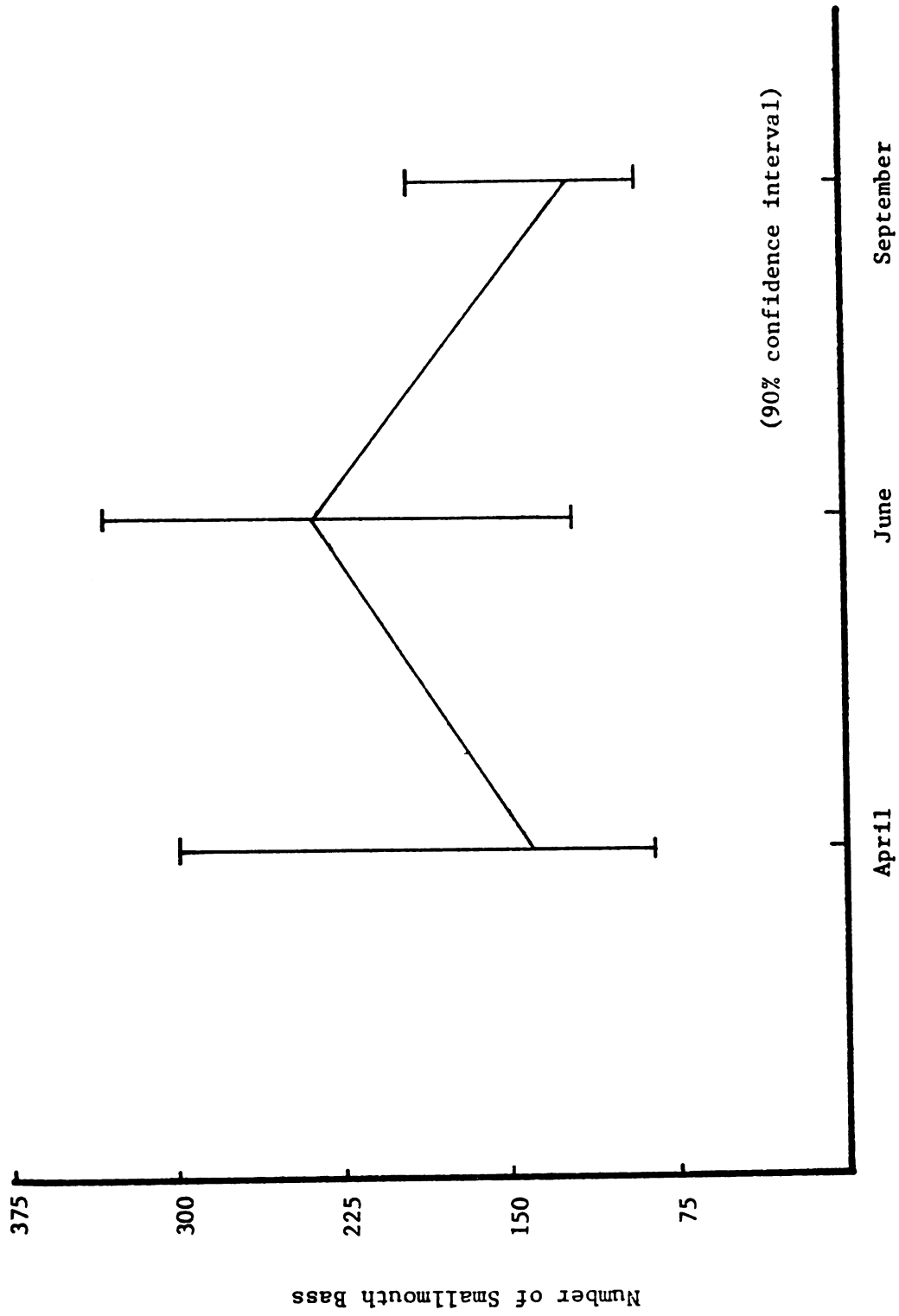


Figure 5. Population estimate of adult smallmouth bass in the study area, 1977.

Table 1. Distribution of large smallmouth bass captured in the study area.

Population Inventory	Size					
	Greater than 400 mm			350-400 mm		
	Section			Section		
	A	B	C	A	B	C
April	2	1	4	8	1	1
June	0	2	1	3	6	0
September	0	3	0	1	5	0

Table 2. Friedman Test for equal catchability among seven size groups of smallmouth bass.

Size Group	Efficiency of Capture		
	April	June	September
greater than 400 mm	0.5	0.0	0.5
360-399 mm	0.33	0.2	1.0
320-359 mm	0.2	0.5	0.375
280-319 mm	0.273	1.0	0.714
240-279 mm	0.2	0.2	0.5
200-239 mm	0.125	0.4	0.556
160-199 mm	0.0	0.636	0.2

$$\frac{2}{2} X = 5.285$$

Therefore, do not reject the hypothesis of equal catchability among the size groups.

five marked fish were captured. All were captured in the same pool about 150 m above the study area.

Few smallmouth bass were captured in the fish traps (Table 3). The bass captured in the fish traps did indicate a general pattern of movement. Before spawning, the bass moved equally in both directions. In general, the fish moving upstream were slightly larger than those moving downstream. After spawning, all bass caught were moving downstream. Five marked fish from the study area were trapped during the year. Four of the five fish were from section C, the farthest upstream section. One bass, marked at the uppermost station, was trapped the following day. The fish had travelled 2.95 km in 10 hours. It was difficult to evaluate the data collected at the weir. As the stream approached base-flow, smallmouth bass became adept at getting out of the traps. Apparently, they were able to locate the entrance to the funnel. Probably a larger number of bass would have moved downstream had the weir not been present.

Larimore (1952) and many others have reported that smallmouth bass are pool fish, though to date no study has adequately defined the necessary requirements of pools for adult fish. Gerking (1949) noted the total volume of pools within the 2-foot contour correlated (+0.866) with absolute weight of fish from a stream section. Also, the Instream Flow Group (1977) published electivity curves for adult smallmouth bass which indicated 2 to 4 ft. was the threshold depth for pools.

If discharge decreased enough, pool depth and volume would diminish until the bass vacated the pool. During the preliminary spring study, there were pools greater than 1 m deep in section A

Table 3. Movement of smallmouth bass through the weir, 1977.

Week	Movement	
	Upstream	Downstream
April 19-23	1	0
April 24-30	0	1
May 1-7	0	0
May 8-14	0	1
May 15-21	3	3
May 22-28 *	1	1
May 29-June 4	0	0
June 5-11	0	6
June 12-18	0	2
June 19-25	0	0
June 26-July 2	0	2
July 3-9	0	2
July 10-16	0	1
July 17-23	0	3
July 24-30	0	0
July 31-August 6	0	0
August 7-13	0	1
August 14-20	0	1
August 21-27	0	0
August 28- September 3	0	1
September 4-10	0	0
September 11-13	0	0

* Period of most intensive bass spawning.

which contained bass over 350 mm. Snorkeling and fishing observations indicated that the large bass left these pools as the depth approached 1 m. One of the objectives of this study was to define the minimum depths and volumes of pools for adult bass. Stream discharge in May did not maintain the normal high level. As a result, no large fish were ever noted in 4 of the 7 pools in section A during 1977. This suggested the population of large smallmouth bass in sections A and C was lower during the study year than most years. Figures 6 and 7 indicate the distribution of pools in Spring Brook during the spring and summer.

Reproduction

Smallmouth bass are spring spawners and spawning activity is closely related to water temperature (Hubbs and Bailey 1938). The first nesting male in Spring Brook was observed 11 May 1977. The water temperature coincided with that reported by Hubbs and Bailey (1938). Twenty-five successful nests were found in the study area between 19-25 May 1977 (Figure 8). No estimate of unsuccessful nests was possible as many successful nests were not found until the fry were observed. Nests in Spring Brook were found in rubble areas adjacent to pools. The nest locations were in pockets of minimum current.

The number of successful nests in each section was 13.3 and 9 respectively. This distribution of nests within the study area was very clumped. With the exception of one nest, all were located along the periphery of a pool (Figure 8). Cleary (1956) and Surber (1943) also noted this phenomenon and hypothesized it was to

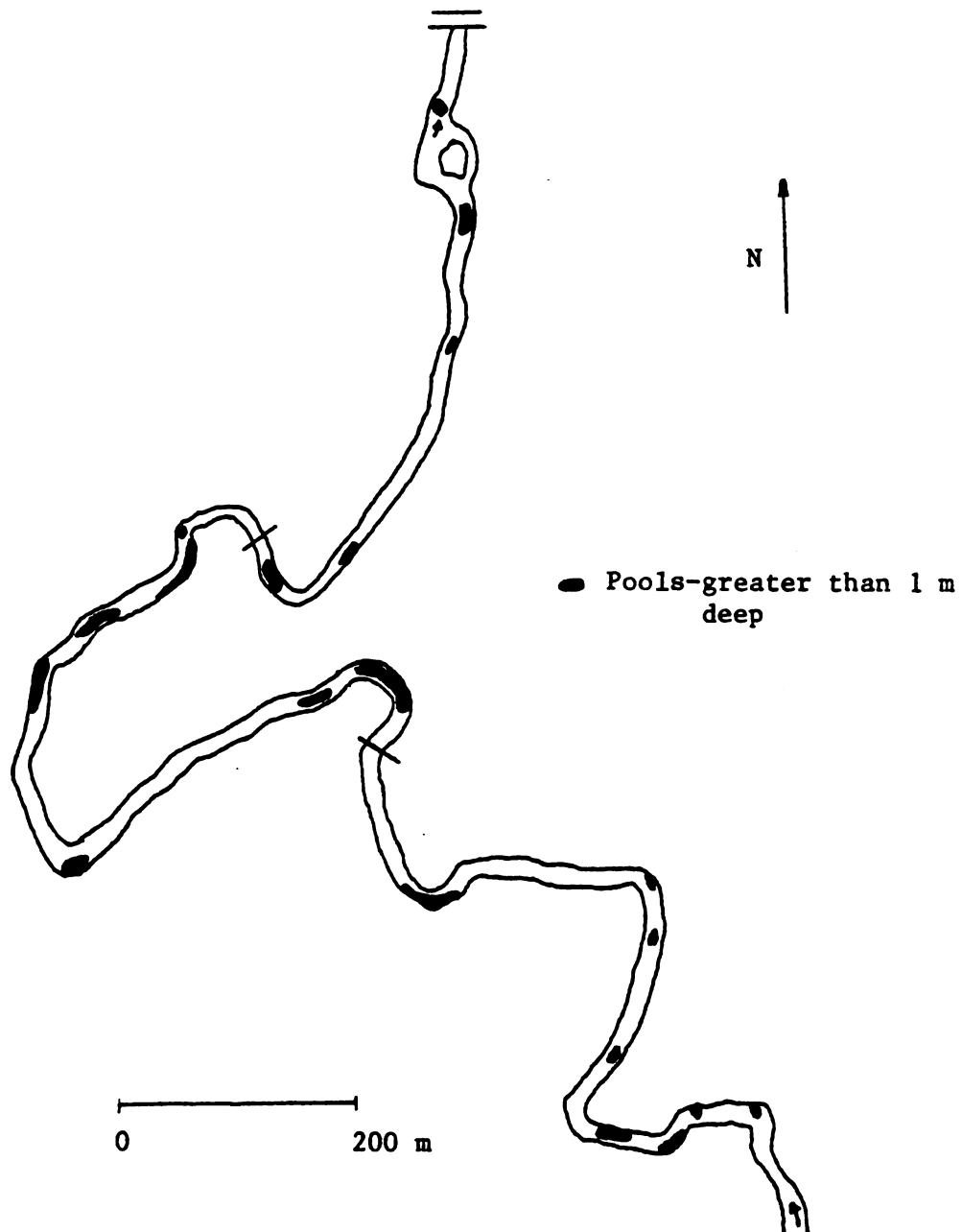


Figure 6. Distribution of pools in the study area of Spring Brook, Spring 1977.

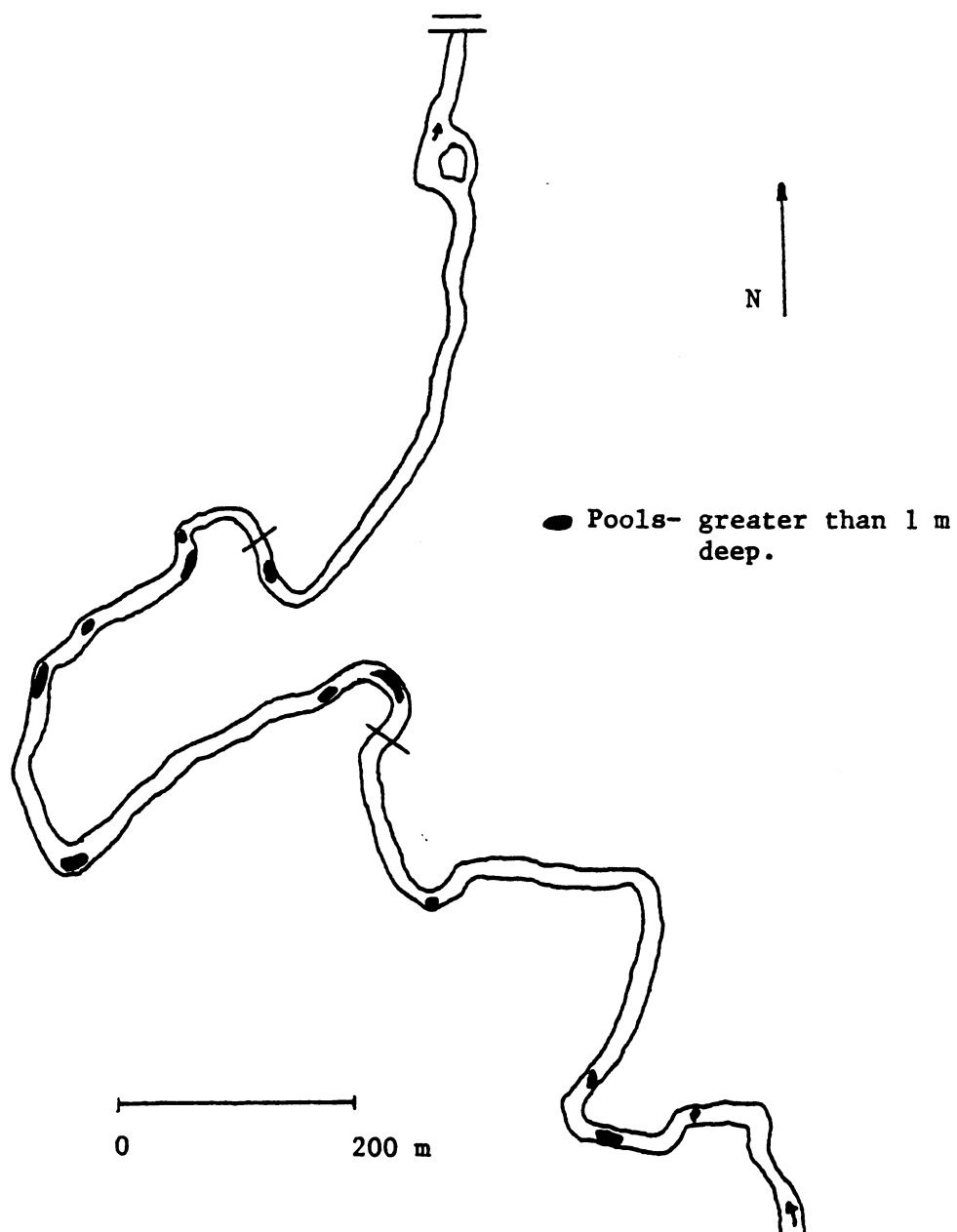


Figure 7. Distribution of pools at base-flow in the study area of Spring Brook, Summer 1977.

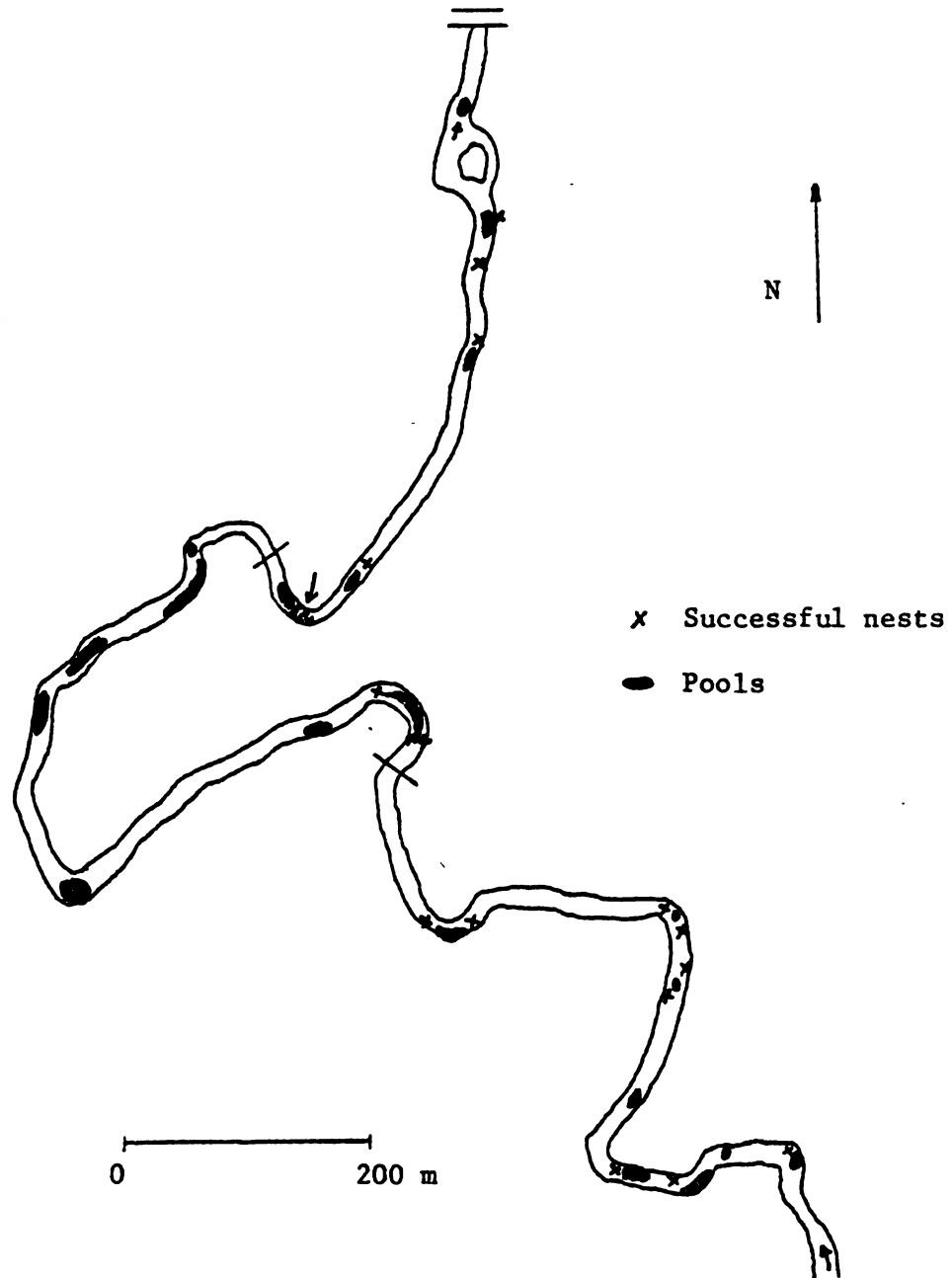


Figure 8. Distribution of successful smallmouth bass nests in the study area of Spring Brook, Spring 1977.

take advantage of the minimum current velocities in the pools. They noted the lack of pools meant no spawning. The pools also provide cover for the nesting bass. An analysis of the habitat in each section provided an explanation for the distribution.

Sections A and C are characterized by long riffles and generally poorly developed pools. In section A, 13 nests were located and 9 of these were associated with 1 pool within 20 m of section C. The remainder of section B is either long shallow riffles or long deep pools with very little rubble. The substrate is not stable during this time in these pools.

Remaining Population Parameters

The major limitation was that the fish could not be aged accurately by the scale method. This problem had previously been observed by Brown (1960) and Keating (1970). Table 4 contains data and back-calculated lengths using the Lee Method for the bass which could be aged accurately. From these data, it is apparent that natural mortality was not the major mechanism regulating the number of large bass in the study area. Smallmouth bass reached 350 mm by the 7th year and the year classes VIII-XIII were well represented.

The creel survey revealed fishing mortality in the study area was minimal. Six fishermen were found in the research area and interviewed during the season. A total of 5 smallmouth bass were kept. Four of the anglers did not keep any fish. In all cases, the fishermen were contacted during their first trip to the study area. The total fishing time was 32 man-days for the season, indicating that there was little fishing done in Spring Brook.

Table 4. Back calculated lengths of smallmouth bass collected during 1977, Lee Method.

Year	Nr.	Class Fish	Length(mm) (Capture)	Lengths at Annuli Formation (mm)													
				I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	
1975	1		215	87	159												
1974	16		235	78	133	197											
1973	26		268	76	128	184	240										
1972	13		298	74	125	179	234	278									
1971	13		309	73	120	168	214	261	297								
1970	7		353	74	128	175	227	278	317	340							
1969	4		385	81	135	184	239	283	326	352	379						
1968	2		374	71	124	170	209	245	280	306	339	360					
1967	1		422	72	140	191	258	294	307	329	360	381	407				
1966	2		388	74	133	211	259	314	335	354	364	377	380	388			
1965	1		470	75	111	173	267	339	380	405	421	437	451	456	470		
1964	1		412	63	153	193	259	283	292	304	323	350	366	381	399	412	
Weighted Averages				75	128	183	233	276	309	341	366	377	397	403	435	412	
Increments				53	55	51	42	34	32	25	11	20	6.3	31	-23		

Summary

The electrofishing inventories indicated the number of bass changed little during the season for the research area as a whole. Few bass moved downstream to the fish traps, so the hypothesis that the smallmouth bass in the study area were migratory was rejected.

The number of large bass in sections A and C varied significantly throughout the year. In spring, these sections had adequate pools and provided good spawning habitat. During the summer, at base-flow, there were few pools in these two sections and few bass. As the stream stage declined, the bass moved into section B, upstream to deeper pools, and downstream to deeper pools. Few bass travelled downstream farther than 1 km. The presence of a large number of bass in Ages VIII-XII and few fishermen indicated mortality is quite low and not the primary mechanism regulating the number of large bass in the study area.

PHYSIOGRAPHY

The occurrence of a large resident population of smallmouth bass in a third order stream is not common in the Great Lakes Region. Forbes and Richardson (1920) noted smallmouth bass were most common in small rivers (Figure 9). Hubbs and Bailey (1938) remarked that smallmouth bass were rare in streams less than 10.6 m wide.

A third order stream which contains a large population of smallmouth bass is in a quasi-equilibrium situation: the stream must have enough groundwater flow to maintain adequate pools during base flow; but not so much groundwater that summer temperatures would be too cold for bass reproduction and growth. The temperature of the groundwater in this area is 9.5 C (Knutilla 1968). This section of the study is an investigation of the geomorphic-hydrologic aspects of the watershed.

Methods

Maps of the bedrock surface, drift thickness, and water table were constructed from well log data and contoured by computer. The deglaciation history of Spring Brook drainage basin was reconstructed from analysis of topographic maps, soils maps, and field observations in conjunction with the above maps.

On 2 and 3 August 1977, when Spring Brook was at base-flow, discharge, water temperature, and conductivity were measured at 10 sites upstream from the study area (Figure 10). Discharge was

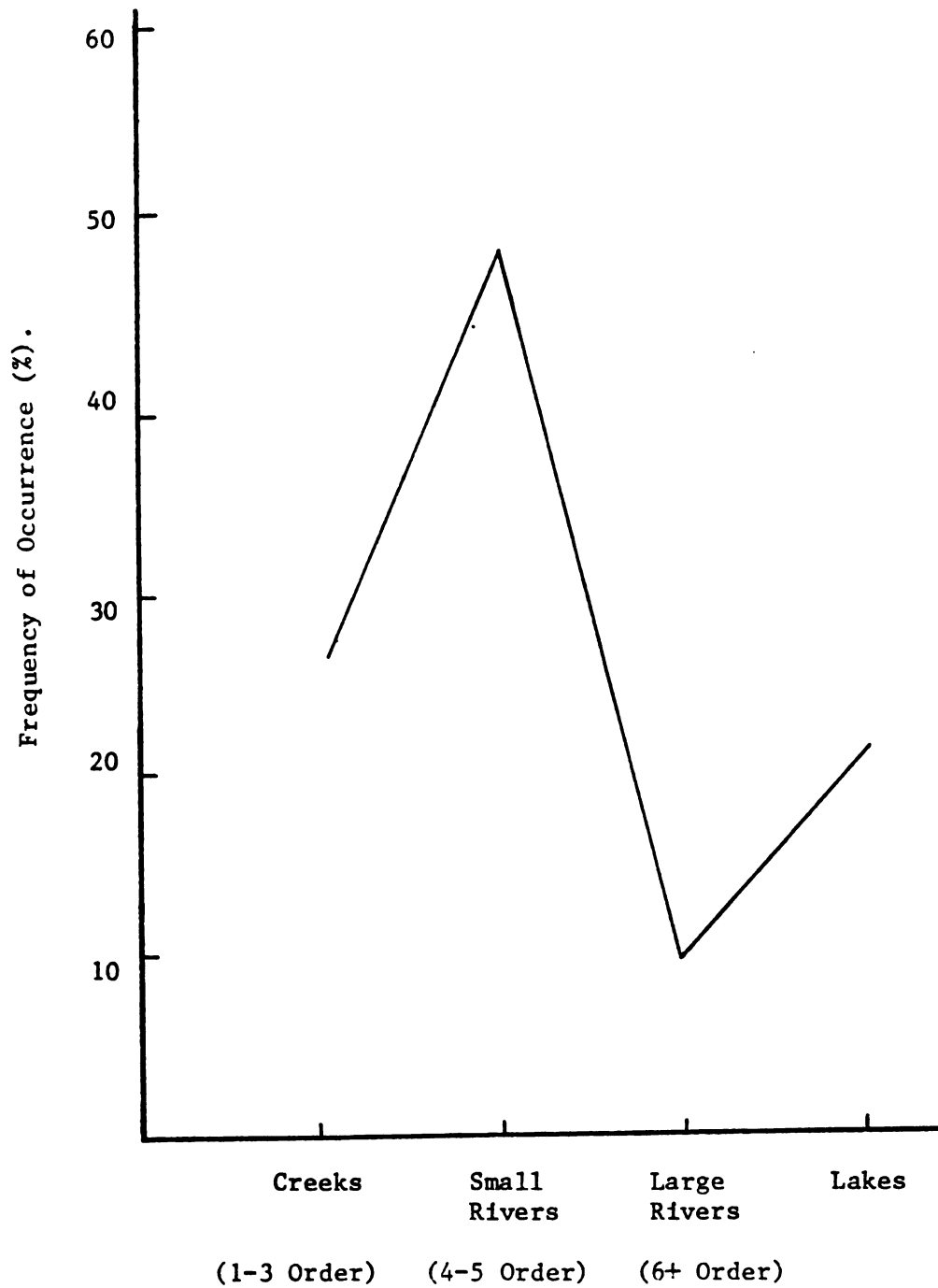


Figure 9. Frequency of occurrence of smallmouth bass in various habitats in Ill. (compiled from Forbes and Richardson 1920).

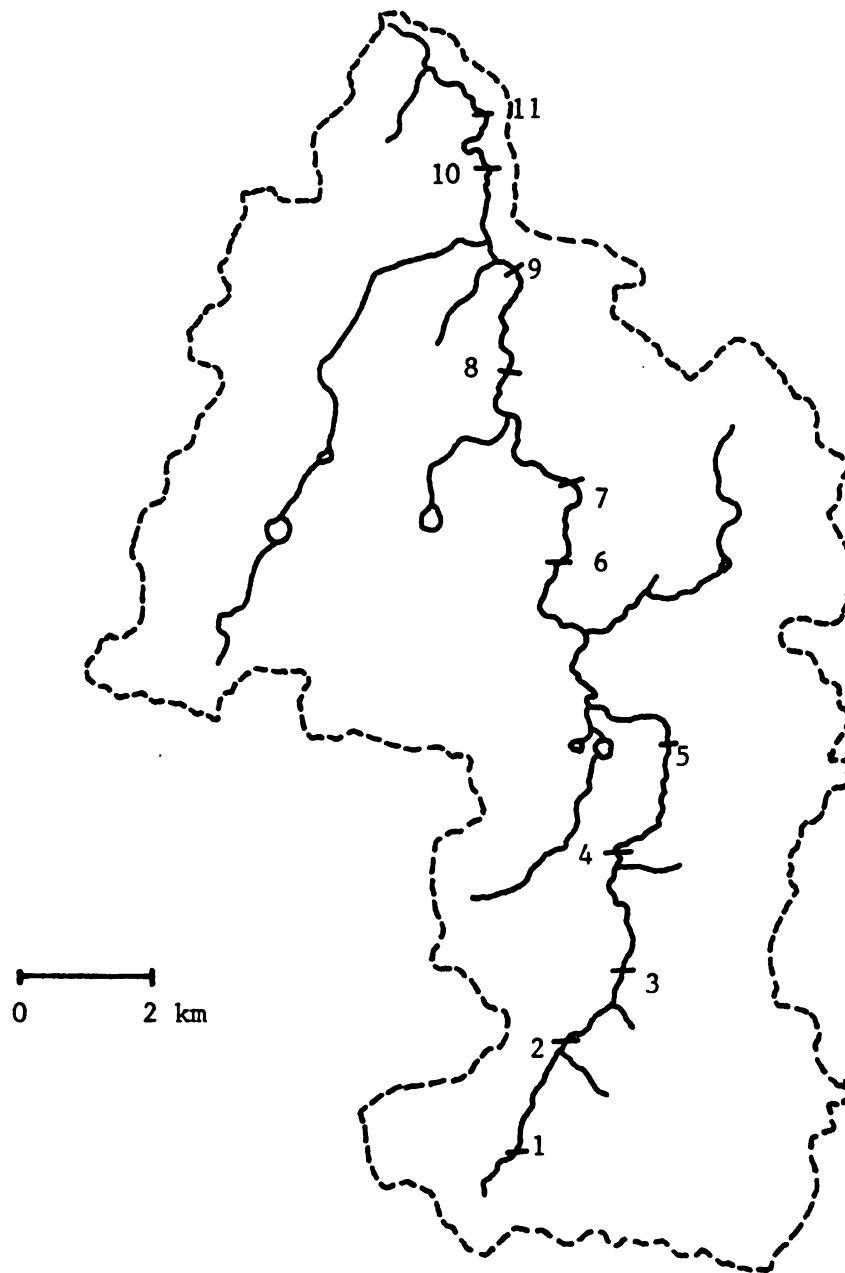


Figure 10. Location of the study sites along Spring Brook for determining the profiles of temperature, discharge, and conductivity.

measured with a Pygmy Gurley meter. The temperature data were collected with a hand-held thermometer. Water samples were taken and the conductivity was measured in the laboratory. The temperature data and the water samples were collected within a 2-hour period during the evening. The temperature data represented the maximum temperature expected during the year at each site, as the air temperature was 30+ C and the stream was at base flow.

The discharge data were used to compute the groundwater yield, i.e. discharge/drainage area, is a standard method to quantifying the rate of groundwater recharge of a stream. The drainage above a site was determined by planimetering the surface drainage area (on a U.S.G.S. topographic map) above the given site.

Temperature and discharge data were collected throughout the year in the study area; however, no records were available to determine the average temperature and discharge regimes. Since air temperature is one of the major factors affecting stream temperature, some data from Lansing, Michigan, 15 miles to the north were included. The nearest continuous recording U.S.G.S. station is on the Grand River in Eaton Rapids. The Spring Brook stream flow characteristics should show trends similar to the Grand River's. The catchment basin of the Grand River above Eaton Rapids lies directly east of the Spring Brook basin (Figure 1), and the normal storm tracks in the region are generally west to east. The water temperature in the study area was monitored from March to September with a Taylor recording themograph.

Results and Discussion

The Spring Brook drainage area is located along the southern edge of the Michigan basin and is underlain by both drift and sandstone of Mississippian age. Drilling logs from oil and water wells within the drainage basin indicate the surface contact point between the Marshall Sandstone and the Saginaw Sandstone closely coincides with the southern boundry of the drainage basin. The bedrock surface map indicates that the general slope of the bedrock is to the north (Figure 11). In addition, the map shows a stream valley in the bedrock. This valley coincides well with the present location of the Spring Brook channel and appears to influence the location of Spring Brook and the direction of stream flow.

The drainage basin was deglaciated about 12,000 years ago. During deglaciation a mantle of drift ranging from 3-70 m in thickness was deposited over the bedrock. Thickness is shown in Figure 12. It appears the shallowest drift occurs in the southwestern corner of the basin; the thickest drift is located in the northern half of the basin. In general, the drift in the upper part of the basin is composed of sand and gravel while the remainder of the drainage area is composed mainly of till.

The deglaciation history of the Spring Brook area is very complex. Hypothetically, the earliest stage of deglaciation is represented in Figure 13. The deglaciated area was basically a bedrock high on the west side and an end moraine (till) on the east side with a valley train in the center. The composition of the drift along the valley train is primarily sand and gravel indicating extensive glacial-fluvial influence. Kames and kame terraces are

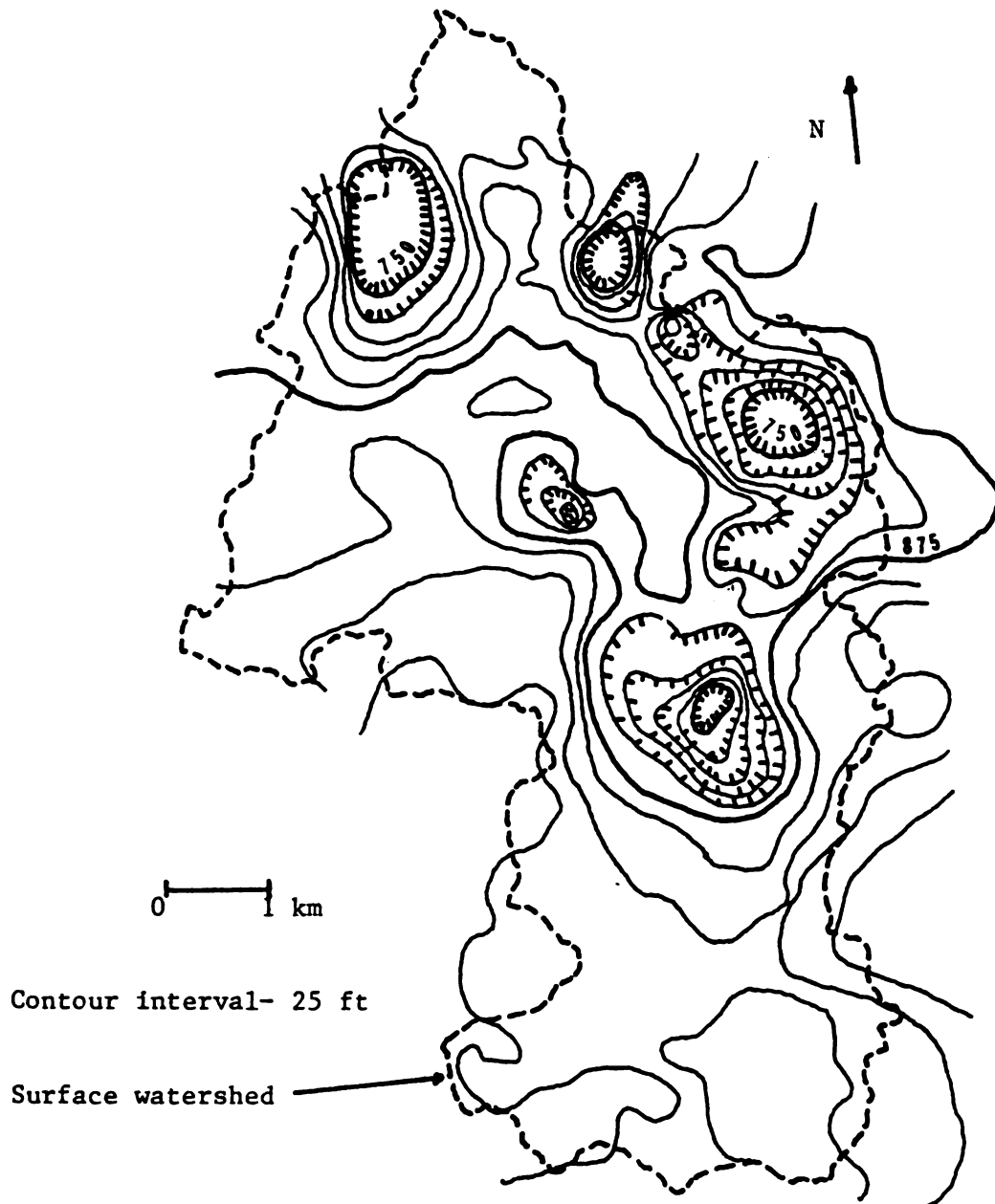


Figure 11. Contour map of the bedrock surface in the Spring Brook basin.

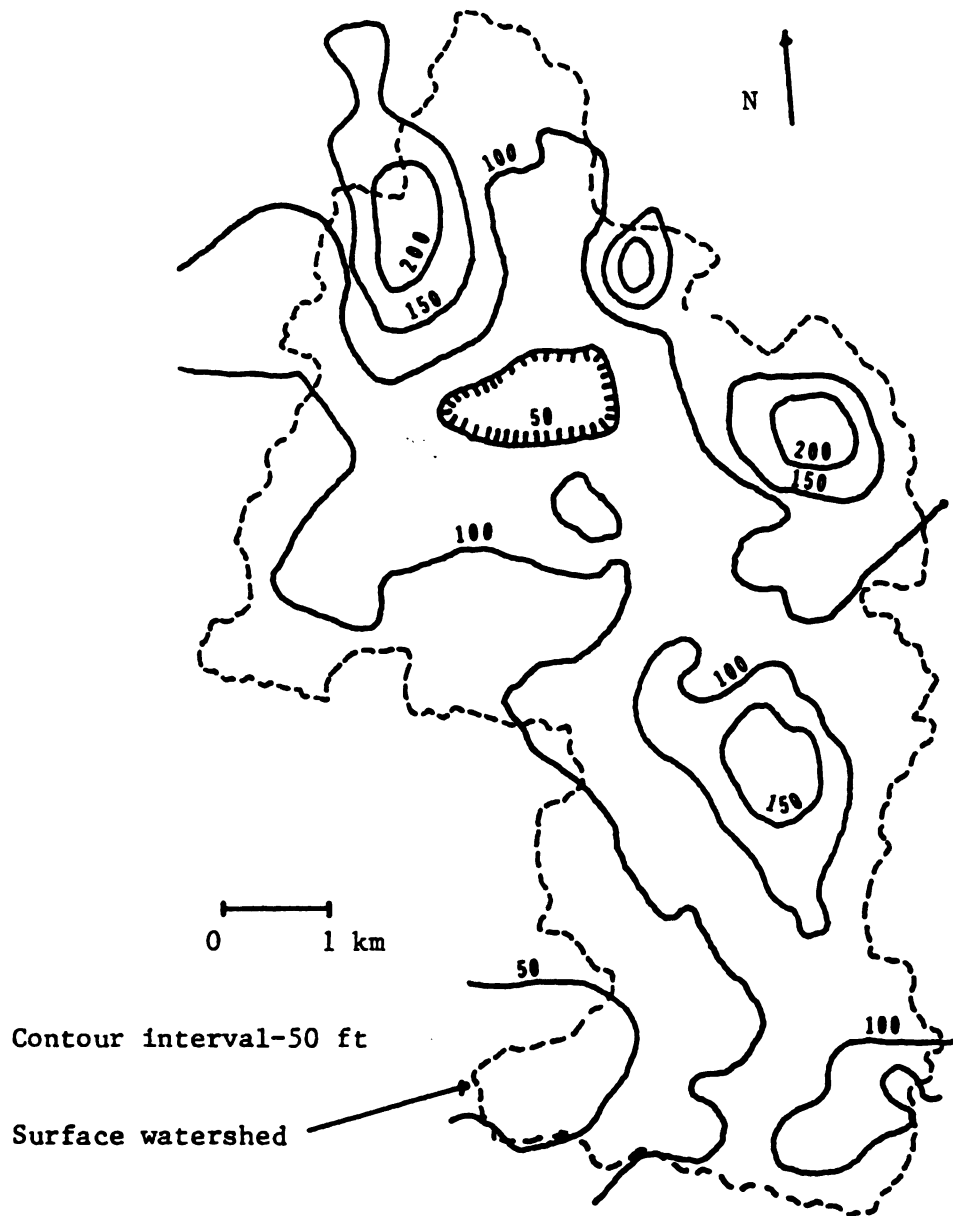


Figure 12. Contour map of drift thickness, Spring Brook basin.

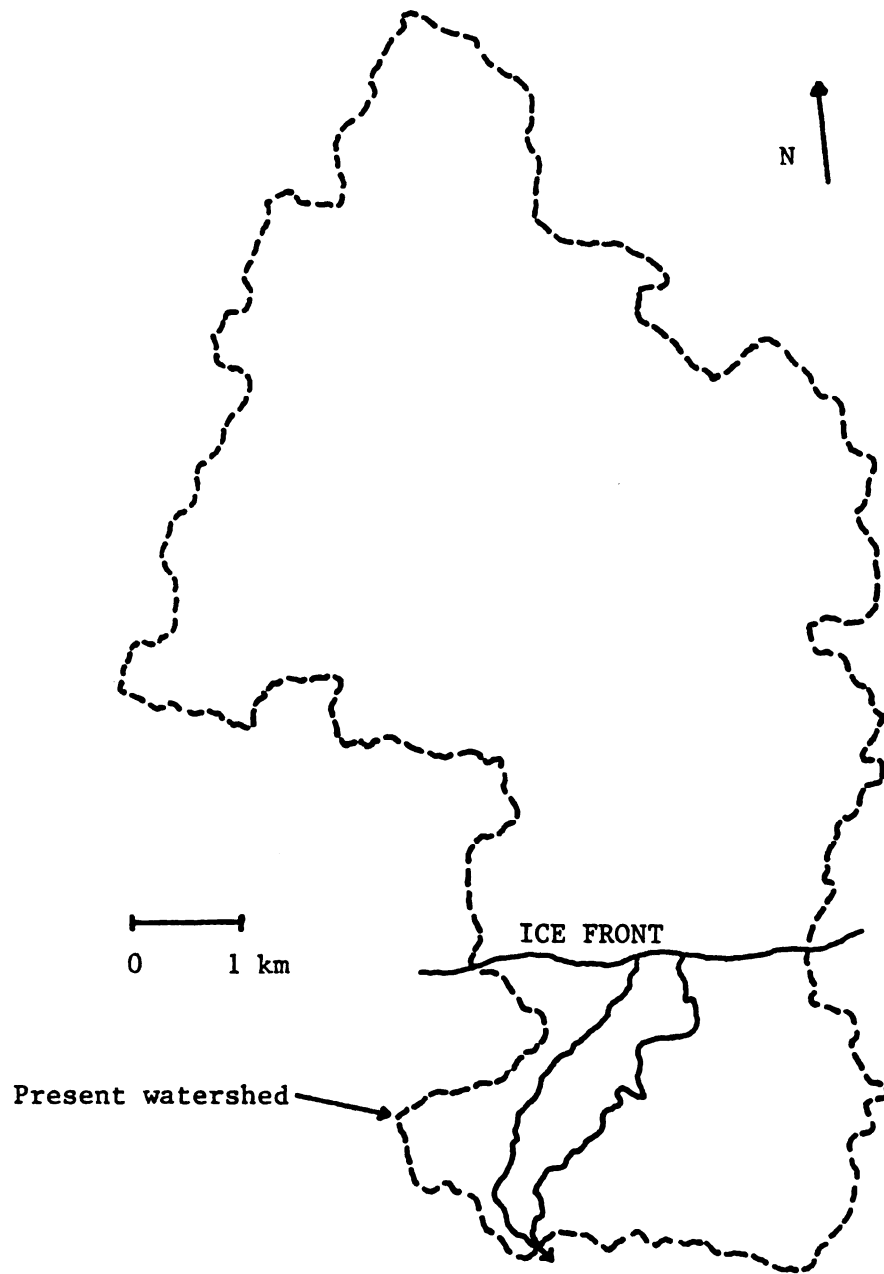


Figure 13. Stage I of the deglaciation of the Spring Brook Basin.

the major landforms along the valley walls and are indicative of glacial stagnation. The drainage outlet was 293 m above present sea level and flowed south (Figure 13). As deglaciation proceeded, a new outlet was established at B (Figure 14), at an elevation of 291 m. The remnants of this channel show extensive development which indicates it was utilized for a greater period of time or had greater discharge than the first channel. The basic drift types and landforms are unchanged from the first stage.

After the glacier had receded northerly past point C (Figure 15), the level of impounded water dropped to approximately 285 m as a new outlet was again uncovered. The next stage of deglaciation involved complete drainage of the impounded water and reversal of drainage. The ice and the surrounding uplands had been higher than the southern and the western outlets. As the ice melted, meltwater no longer could be impounded at the high level. As the ice margin retreated northward, a well developed outlet was formed along the northern rim of the basin, causing the meltwater to flow northward into the developing Grand River (Figure 16). Up until this time, Spring Brook had been part of the glacial Kalamazoo River system.

The ice then apparently retreated to the northwest (Figure 17). A lower outflow channel was then developed; this channel is the present Spring Brook channel. As downcutting progressed, the lake was drained and cobble and boulders were left accumulated in the channel. At some stages, the channel bed undoubtedly became armor-plated thus preventing further downcutting until a flood removed the armor-plate.

The predominant sediment type in the formerly impounded area

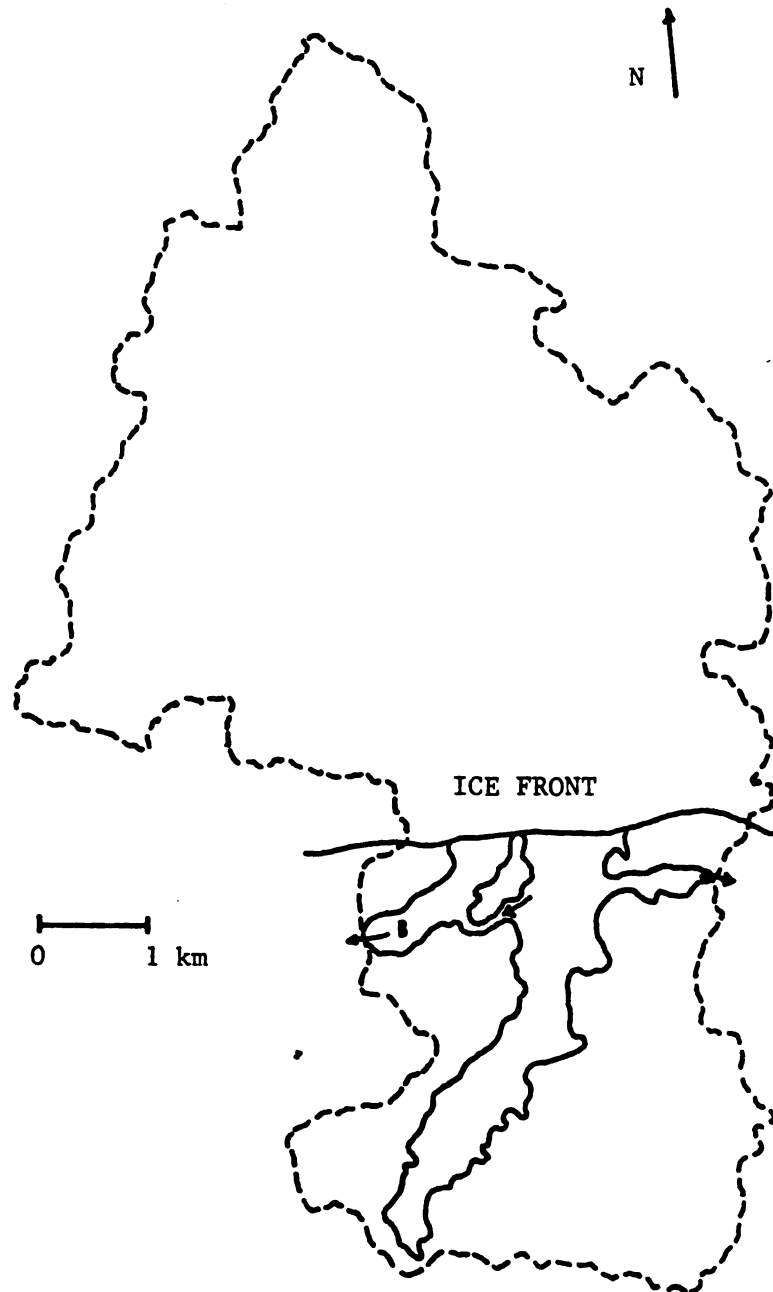


Figure 14. Stage II of the deglaciation of the Spring Brook basin.

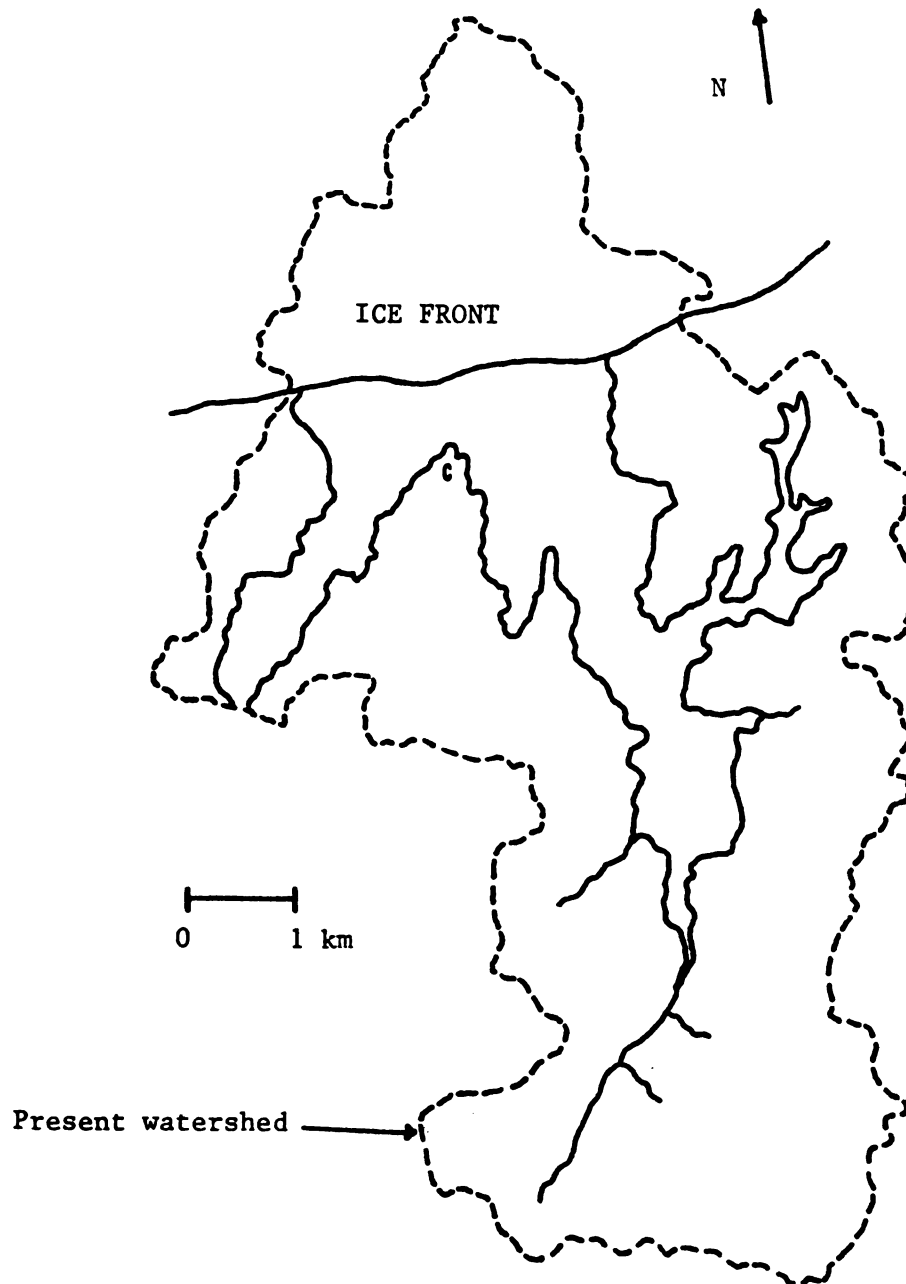


Figure 15. Stage III of the deglaciation of the Spring Brook basin.

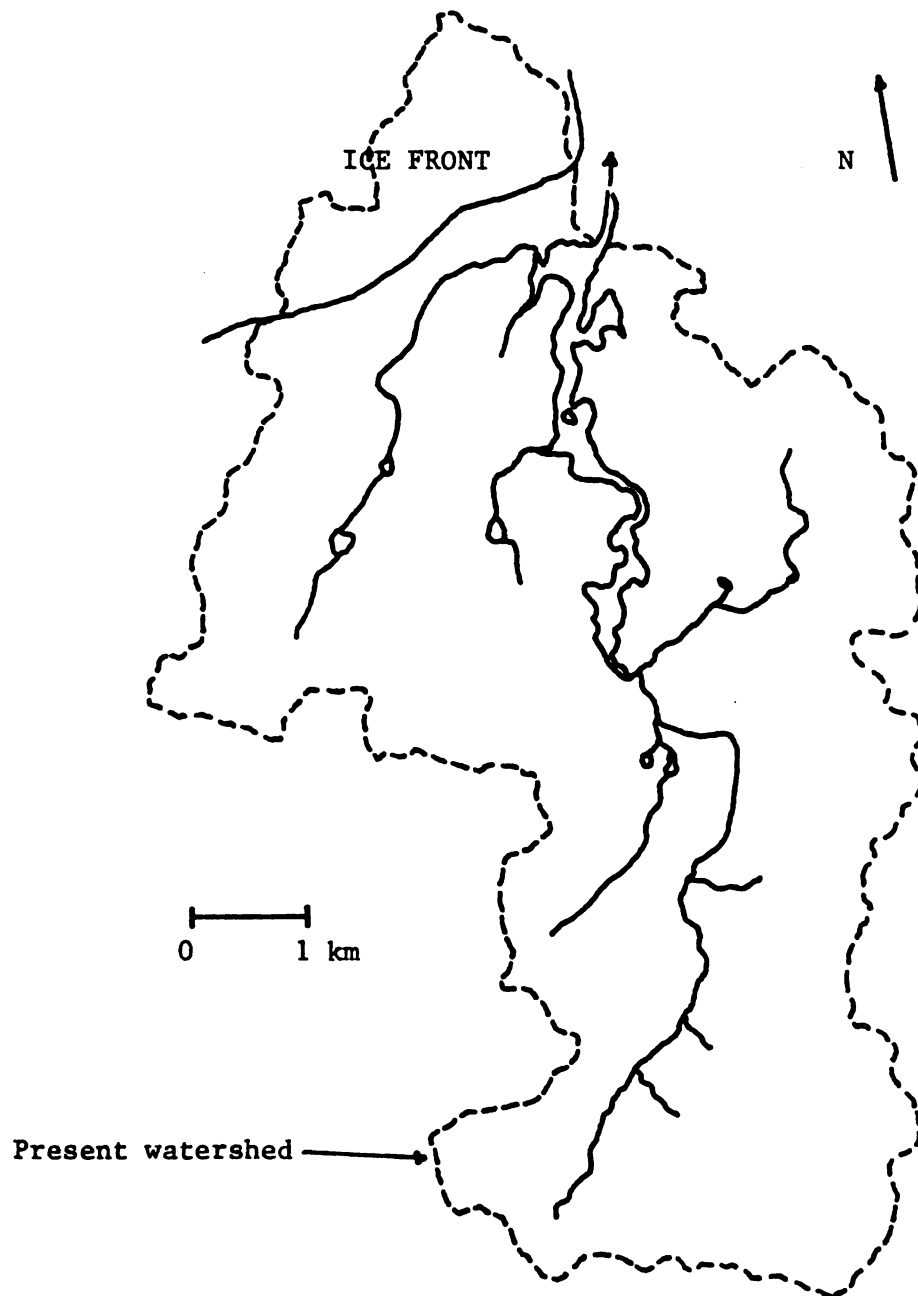


Figure 16. Stage IV of the deglaciation of the Spring Brook basin.

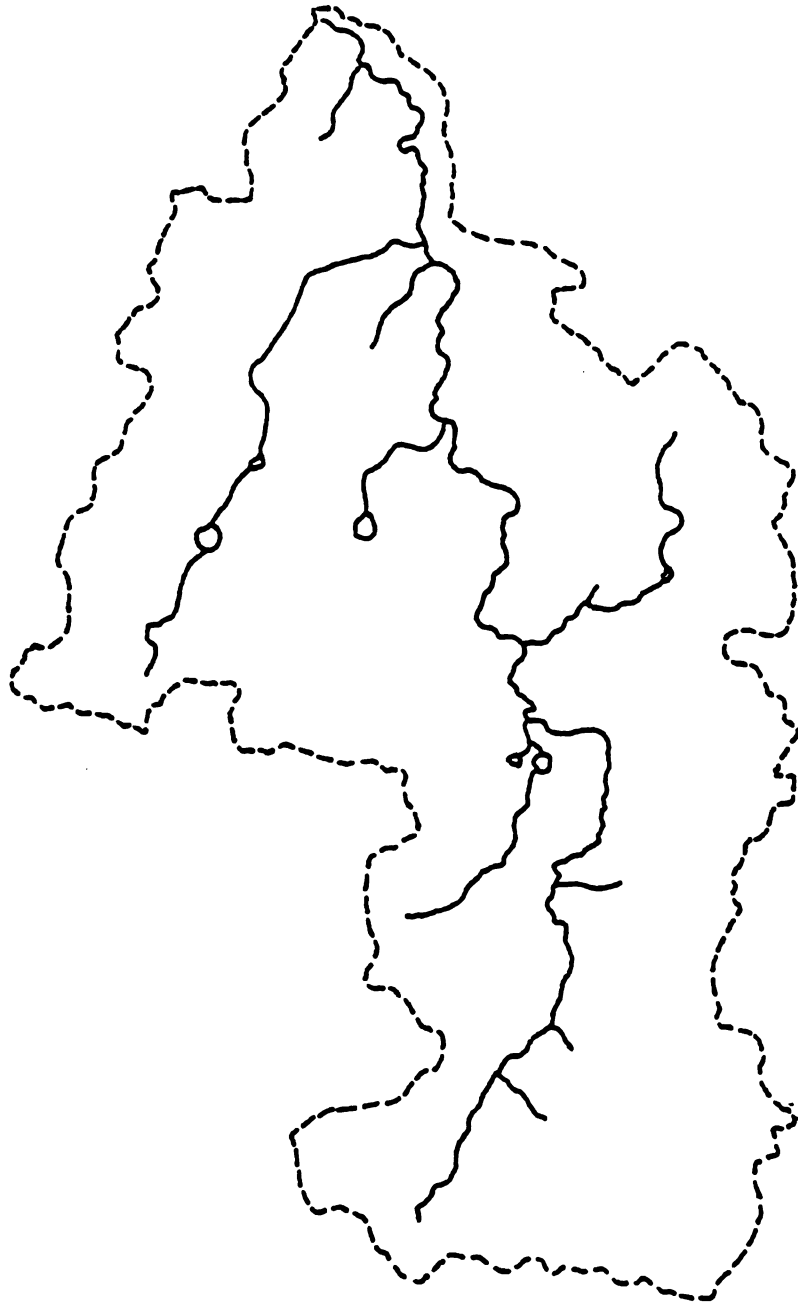


Figure 17. Stage V of the deglaciation of the Spring Brook Basin.

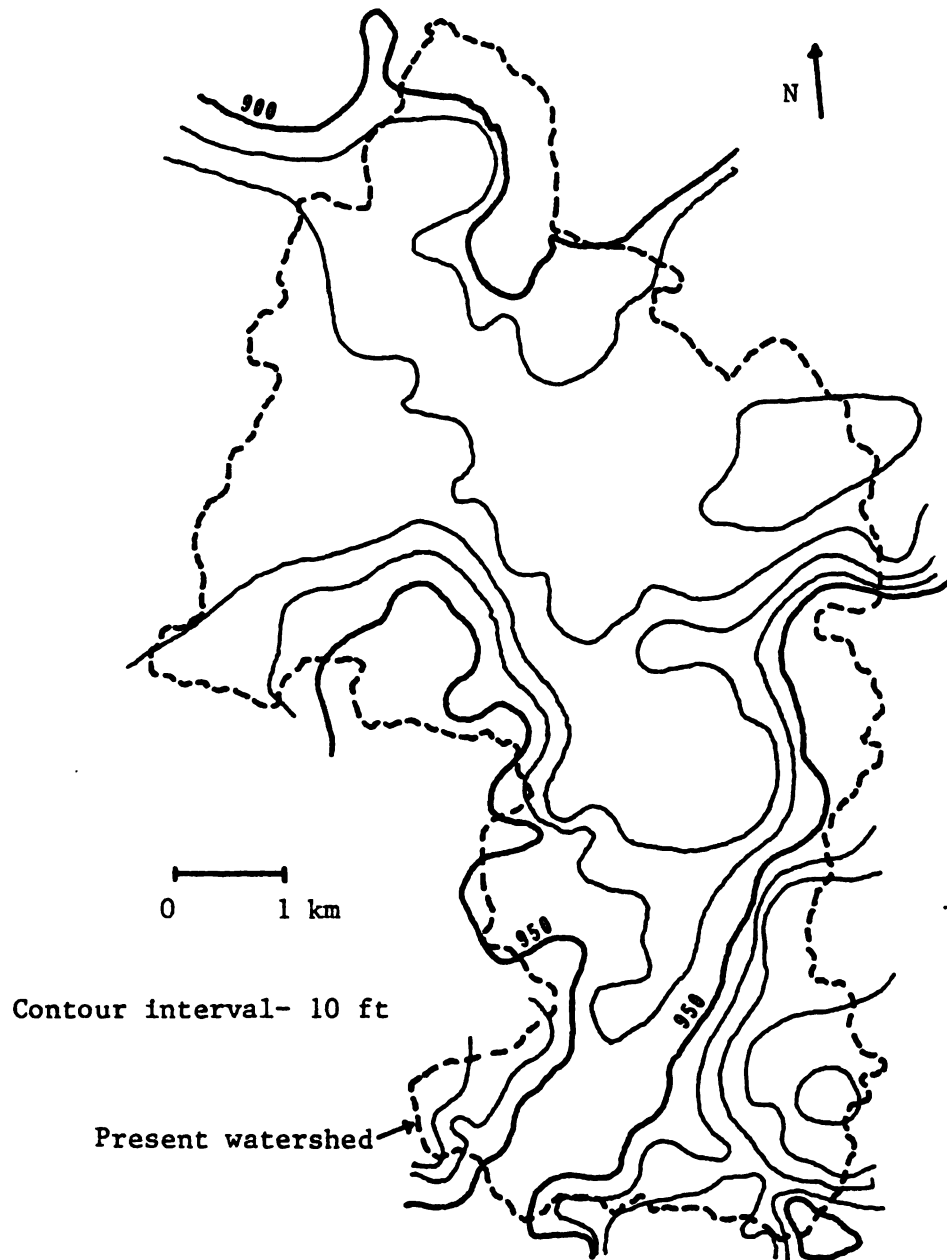


Figure 18. Contour map of the water table in the Spring Brook basin.

is clay, indicative of standing water. The soil types in the shallow areas of the old glacial lake are predominantly Carlisle Muck (0.4 m deep).

The Spring Brook drainage basin receives an average of 81.3 cm of precipitation annually and has mean annual runoff of 25.4 cm (Bent 1970). Knutilla (1968) reported the groundwater yield for Spring Brook was lower than adjacent streams.

There are two components of runoff (groundwater and surface) and the portion of each component has a profound influence on the flow-duration curve. In general, the more groundwater discharge into the stream, the more stable the flow and the greater the base-flow discharge (Henderson and Doonan 1972).

The amount of groundwater entering a stream is the result of physiographic parameters, probably the most important being the permeability of the soils and drift. Water falling on sandy, well-drained soils has a greater tendency to percolate down to the water table than water falling on clay soils. Permeable soils and drift provide much greater groundwater recharge capability than less permeable soils and drift. More permeable drift also allows greater horizontal movement through the drift the greater the groundwater discharge into the stream. The permeability of soils is largely determined by the parent material, in this region, usually glacial drift. Drift composed of sand and gravel is much more permeable than drift composed primarily of clay. Glacial features primarily constructed by glacial-fluvial processes are characteristically composed of sorted sand and gravel; they are highly permeable. Examples of these features include outwash plains, and kame

terraces. Glacial features composed of till generally are not as permeable. The least permeable landforms are the glacial lake bottoms.

The watertable map suggests the typical situation, i.e. most of the groundwater in the basin is moving toward the stream channel (Figure 18). Horizontal movement of groundwater out of the drainage basin is probably not the reason for Spring Brook's lower than expected base flow.

The discharge profile indicated groundwater recharge into the stream channel was not constant (Figure 19). Analysis of the yields indicated the overall groundwater input declined from station 4 to 11 (Table 5). The groundwater yields of the 3 sections of Spring Brook were significantly different. The results were those predicted from the analysis of the drift types. The upper third of the basin is constructed of highly permeable glacial-fluvial drift. The groundwater input to the stream is high in the section. The middle section of the stream is a glacial lake bed. The clay sediments significantly reduce the groundwater input to the stream. In the lower section, which includes the study area, the stream transects a till plain. The groundwater yield is intermediate between the other two sections.

Temperature measurement has been used by hydrologists to determine the relative amounts of groundwater inputs to stream reaches. During summer base flow, the greater the groundwater input the cooler the stream temperature. The temperature and groundwater recharge to the stream were negatively correlated in Spring Brook (Figure 19).

Conductivity measurement is also a standard technique for

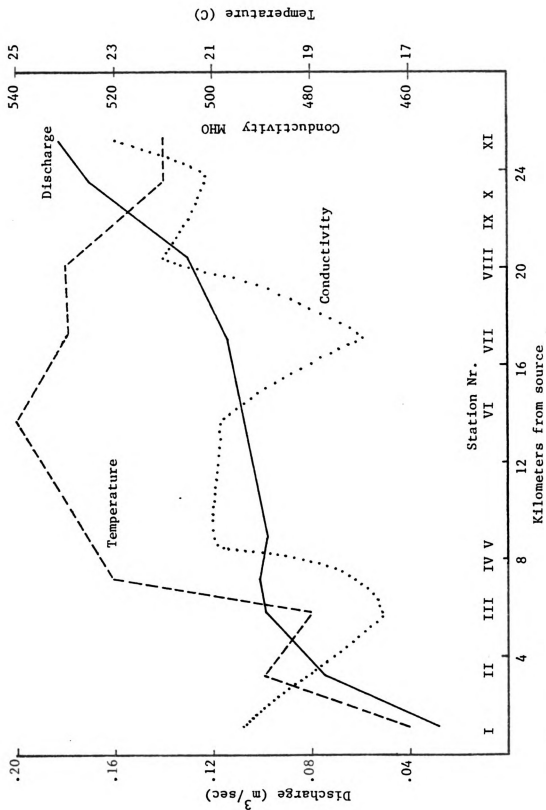


Figure 19. Profiles of temperature, discharge, and conductivity along Spring Brook, Aug 2, 1977.

Table 5. Groundwater yield for selected subbasins in the Spring Brook drainage basin.

Subbasins	Groundwater Yield (M ³ /km ²)
Station 4 (Section 1	.0028
Station 7	.0014
Station 11	.0013
Section 2 (Stations 4-7)	.0002
Section 3 (Stations 7-11)	.0012

quantifying groundwater input to a stream reach. The discharge and conductivity profiles were not correlated well in Spring Brook (Figure 19). The conductivity increased significantly in the middle section of the basin. This is the section which received little groundwater input.

Hack (1957) determined that channel slope was not directly related to the size of substrate material over an entire region, but there was a good correlation for a given stream. In the study area of Spring Brook, as the resistance of the channel bed increased when rubble and boulders accumulated in the channel, one of the predicted changes in the hydraulic characteristics would be an increase in channel slope (Leopold et al. 1964). The preferred habitat of smallmouth bass is streams dominated by rubble-boulder substrate (Hubbs and Lagler 1958). Therefore, it is not surprising that the distribution of smallmouth bass in Spring Brook is correlated with the highest stream gradient. This phenomenon was earlier reported by Trautman (1942) and Huet (1959).

The temperature and discharge regimes were unusual during the study year (Tables 6 and 7). The temperature regime was probably substantially higher during the early spring in the study area. The smallmouth bass spawned about two weeks earlier than normal. The U.S.G.S. data from the Grand River indicated the winter discharge was higher than normal but throughout the rest of the year the discharge regime was about average.

Table 6. Monthly deviations in air temperature from average, Lansing, MI, Spring 1977.

Month	Deviation from normal (°F/day)	Remarks
March	+7.3 °F/day	warmest 33 years
April	+4.3 °F/day	warmest 22 years
May	+5.5 °F/day	warmest 55 years

Table 7. Monthly deviation in precipitation from average, Lansing, MI, 1977.

Month	Deviation from normal ("/month)
March	0.29 inches more than average for the month.
April	0.37 inches less than average for the month.
May*	2.70 inches less than average for the month.
June	0.03 inches more than average for the month.

* (Until May 30, total for month was 0.1 inches- Total for the month was 0.62 inches- lowest in history).

Summary

The occurrence of a large number of smallmouth bass in a third order stream is not common in the Great Lakes Region. The investigation of the geology and hydrology of the Spring Brook basin provided an explanation for the distribution of smallmouth bass in Spring Brook. The upper third of the basin provides the groundwater necessary to maintain adequate base-flow during the summer. The middle section of the basin has very little groundwater input and the stream temperature rises rapidly as it passes through the marsh. This provides the necessary temperature and discharge regimes in the study area for smallmouth bass. As the stream downcut through the till which impounded the glacial lake, boulders and rubble accumulated in the channel, providing the preferred habitat of the smallmouth bass.

SMALLMOUTH BASS-ROCKBASS INTERACTION

The study of a single species is of little value by itself if competitors exist in the system. Usually the population of a given species is a result of the interaction with its competitors. A crucial element of the concept of niche is that they are evolved in the presence of competitors.

Forbes and Richardson (1920) reported the rockbass had an extremely high associative coefficient (6.24) with the smallmouth bass. The interaction of these two species should be of interest to fisheries biologists and ecologists. The geographic distribution of the two species is similar. The original range was northern Minnesota to Quebec, south to eastern Oklahoma and Alabama (Hubbs and Lagler 1958). Their preferred habitat is the same. They are usually found in the same stream sections. They eat the same types and sizes of prey (Table 8).

During their first year, rockbass and smallmouth bass both feed on copepods, cladocerans, and dipterans. As they attain a larger size, insects begin to gain importance. My field notes indicated the smallmouth bass spawned earlier in the year than the rockbass. This provides a mechanism to avoid competition. Hubbs and Bailey (1938) reported the smallmouth bass spawned earlier than other centrarchids in the same area.

After the two species attain 70 mm T L, crayfish is their

Table 8. Food items of smallmouth bass and rockbass (From Carlander, 1977).

Size	Food Items	
	Smallmouth bass	Rockbass
8 mm	Diptera Copepods Cladocerans	
12 mm	Diptera Copepods Cladocerans Fish fry	
20 mm		Copepods
40 mm	Insects Small fish	
45-70 mm		Insects Crustaceans
70 + mm	Crayfish* Fish	Crayfish* Fish

*Where abundant, crayfish made up most of the diet.

preferred food. Keast and Webb (1966) noted the mouth morphology of the rockbass reflected their major food niche. Their terminal, scoop-like mouth with moderate aperture and strong jaws were ideally suited for predation on crayfish. The mouth morphology of the smallmouth bass is almost identical.

No study could be located documenting the size distribution of both species and relating the size of crayfish eaten. Mouth size of both fishes is similar, and the maximum size of crayfish eaten by fish of equal lengths should be similar. This section investigates the interaction of the smallmouth bass and the rockbass for their preferred food item, crayfish.

Methods

Fish

Fish were brought into the laboratory to determine the maximum size of crayfish that a fish of a given size of each species could eat. Each fish was isolated in a 63-liter aquarium. Three fish of each species were used. Each fish was fed young-of-the-year crayfish during the acclimation period. For a test, the fish were starved 24 hrs. and then presented a crayfish of a given size. The fish were given 24 hours to eat the crayfish.

On three mornings in August, smallmouth bass and rockbass were collected with backpack electrofishing equipment. Mornings were selected because in a previous study on the food habits of rockbass, a higher percentage of crayfish was noted in the morning than the afternoon. Smallmouth bass less than 300 mm TL and all rockbass were kept. The fish were immediately placed in 20% formalin and

brought to the laboratory, where body lengths (TL) of fish were measured and the stomach contents recorded. Of 17 smallmouth bass and 24 rockbass examined, crayfish were by far the most frequently found prey item. Of 9 smallmouth bass with food in their stomachs, all but one contained only crayfish. The exception was a young-of-the-year bass which contained only Gammarus sp. Of 13 rockbass which contained food, all but 4 contained crayfish. The exceptions included: Hexagenia sp nymphs, snails, clams, and a terrestrial beetle. Those crayfish were measured for which the cephalothorax was still intact. When the cephalothorax was not intact, crayfish length was estimated by comparing identifiable parts with crayfish of known size. The stage of digestion was observed.

Crayfish

The number and size distribution of crayfish in various habitats of the study reach were determined by the transect method. A quadrat was placed and every cobble was lifted and checked for crayfish. If a crayfish was seen, I attempted catching it in a small net. A crayfish was followed even outside the quadrat until caught or lost. If lost, its size was estimated. Movement in and out of the quadrat was assumed to be 0. The stream margin contained extensive growth of Lizard Tail (Saururus cernuus). This habitat was also sampled by the quadrat method using a quadrat size of 1 m by 0.5 m.

The pools represented a sampling problem. The substrate is primarily boulders. In addition, many authors noted Orconectes propinquus, the most abundant crayfish in the study area, is nocturnal and makes migrations into the riffles at night. In the study area,

snorkeling revealed all the large crayfish were in the pools and they were active during the day as well as during the night.

These crayfish were sampled at night utilizing the Petersen mark and recapture method as outlined by Vannote (1963). The crayfish collected were marked by clipping the pleopods with a pair of nail clippers. The crayfish collected were released within the riffle area and care was taken to place them next to a rock. The same area was sampled the following evening.

Results and Discussion

Fish

The laboratory study suggested the maximum size of crayfish eaten was the same for a fish of a given size of either species (Figure 20). This was the result Keast and Webb (1966) had predicted. Size of food and size of mouth were directly related, and they were related to length.

The field data indicated smallmouth bass and rockbass eat the same size crayfish (Figure 21). The data suggested the size distribution of crayfish ingested by the smallmouth bass was correlated closely with the length of the fish. For the rockbass, this was not the case.

Keast and Webb (1966) hypothesized morphology was correlated with food niche. They noted no two species in their study were identical in all their characteristics. Using Keast and Webb's (1966) criteria, body form was the only characteristic which the smallmouth bass and the rockbass did not have in common. The rockbass has a sub-gibbose body form, while the smallmouth bass has a

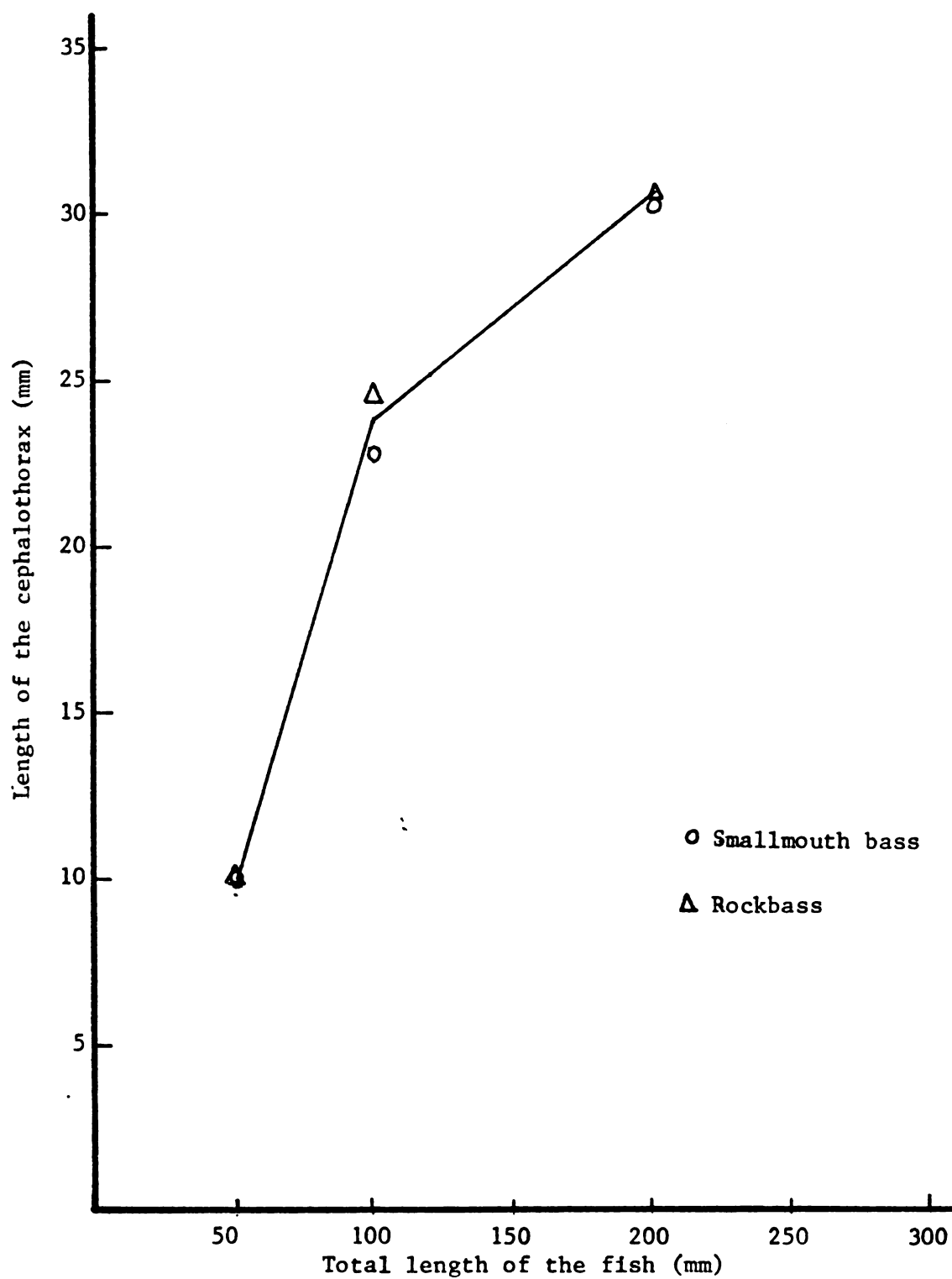


Figure 20. Maximum size of crayfish eaten by rockbass and smallmouth bass of a given length.

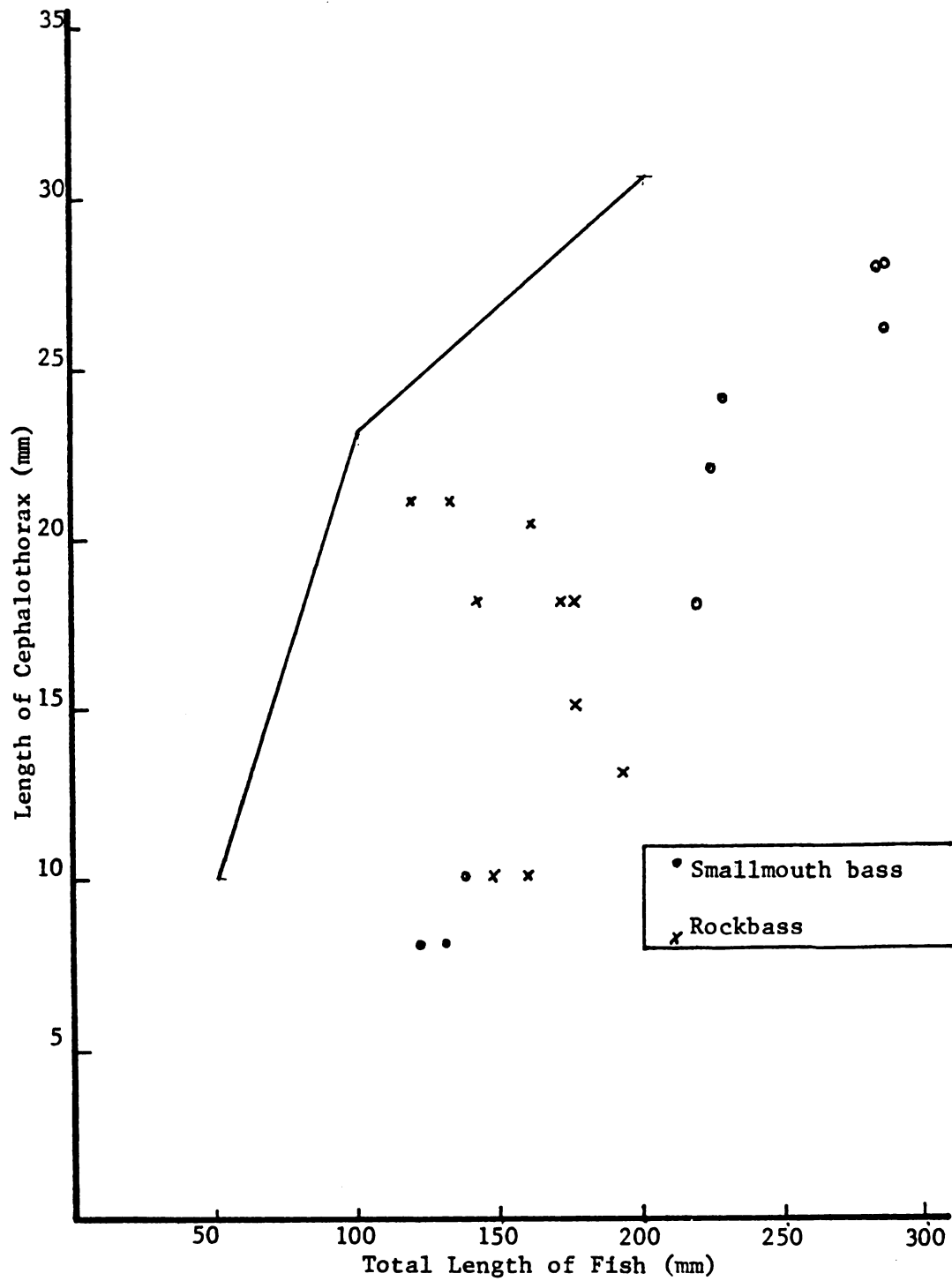


Figure 21. Size of crayfish eaten by smallmouth bass and rockbass of a given length from Spring Brook, August 1977.

compressed fusiform shape. Following the theoretical lines of Alexander (1967) and Hynes (1970), the smallmouth bass's form is more streamlined and adapted for greater efficiency in the current than the rockbass's form.

The foraging behavior of the two species is related to body form, Gerking (1953) and Klauda (1968) reported the smallmouth bass was a pursuit predator with a much larger home range than the rockbass. During this study, Age-I and II smallmouth bass were often observed slowly patrolling the riffles and areas adjacent to the riffles. On several occasions while snorkeling, a unique feeding behavior was observed. An Age I or II smallmouth bass would station itself about 0.5 m behind a feeding hog sucker. As the hog sucker fed, it moved gravel and rubble, disturbing the young-of-the-year crayfish and stonefly nymphs. These drifting invertebrates were easy prey for the smallmouth bass. In general, adult bass up to about 2 kg patrol the pools and adjacent areas leisurely throughout the day. They must see many crayfish and appear to select crayfish according to size. This foraging strategy would minimize intraspecific competition among various size groups. Smallmouth bass over 2 kg were always located in the deepest pools. They did not appear to patrol their pools continually during the day as the smaller size groups. Active fish over 2 kg were usually observed at dawn pursuing minnows in or adjacent to pools.

The rockbass, on the other hand, is seldom found in the riffles. From electrofishing data, snorkeling, and walking the stream, the rockbass was usually in the quieter areas of the stream especially in areas with abundant cover. Keast and Webb (1966) described the

foraging behavior of the rockbass as "hang and rush". Few feeding rockbass were observed in the field. However, one could speculate they patrol a small home range and probably select any prey item observed. This strategy would minimize energy expenditure in search of prey.

Crayfish

Crayfish were not randomly distributed. The young-of-the-year were most abundant in the shallow rubble riffles and in the vegetational areas along the stream margin (Table 9). They did not appear to be nocturnal or migratory. The yearling crayfish were distributed among the large cobbles in the riffles, in the pools, and in the vegetational areas along the stream margin. They appeared to be active throughout the day and they migrate into the riffles at night. The large crayfish were found in the pools among the boulders. They were active during the day as well as at night. They also migrated into the riffles at night.

A major sampling problem was noted during the mark and recapture part of the study. The first night 80% of the crayfish were males. The second night only 55% of the population were males. This suggests the crayfish move extensively in the stream. Also, few crayfish were recaptured.

Summary

From the data concerning foraging behavior, crayfish distribution, and fish distribution, the following hypothesis was formulated: smallmouth bass and rockbass partition the habitat such that direct competition is minimal, thereby allowing these two similar species

Table 9. Size distribution of crayfish from two habitats in the study area.

Size Distribution (Length of Cephalothorax) (mm)	Frequency of Occurrence	
	Vegetational Habitat (28.5 crayfish/m ² - based on four quadrats)	Riffle Habitat (34 crayfish/m ² based on three quadrats)
6	.03	.06
7	.04	.02
8	.02	.06
9	.11	.18
10	.22	.30
11	.17	.19
12	.11	.09
13	.08	.00
14	.04	.05
15	.01	.02
18	.01	.00
19	.03	.00
20	.02	.00
22	.01	.01
23	.02	.01
24	.01	.00
25	.02	.01
26	.03	.00
27	.03	.00
30	<u>.01</u> 1.0	<u>.00</u> 1.0

to coexist. Competition for crayfish appeared between rockbass 100-200 mm TL and smallmouth bass 140-220 mm TL (Figure 21). The size of the crayfish selected by both species were the young-of-the-year. These crayfish were abundant in two areas of the stream: 1) in the riffles, 2) in the vegetational areas along the stream margin. If the smallmouth fed primarily in the riffles and the rockbass in the vegetation along the stream, the habitat would be effectively partitioned. To test this hypothesis, I pose the following field experiment. With the aid of several people, collect and paint a code on the cephalothorax of the crayfish identifying the habitat collected in. Three classes would be easiest; riffles, pools, and margin of the stream. Wait 24 or 48 hours. Then collect rockbass and smallmouth bass with electrofishing gear and quantify the crayfish ingested by the fish. Also, collect crayfish soon after collecting the fish to ascertain the movement of crayfish among the three habitats.

Ecological investigations of this type provide a framework with which to organize some of the observations of naturalists. Hallam (1959) observed rockbass were more numerous than smallmouth bass in streams with a lower percentage of fast current. Reynolds (1965) noted the years with the best smallmouth bass growth were those with the lowest water levels. Brown (1960) noted growth of the smallmouth bass was slowest during years of high water and growth of rockbass was greatest during the years of high water.

IMPLICATIONS FOR MANAGEMENT

An assessment of the distribution and abundance of smallmouth bass within Michigan is basic for any management program. This indicates intensive sampling of each stream is necessary because of the difficulty in capturing smallmouth bass.

The results of this study indicated the following system should work well in establishing sampling sites. Using the Forbes and Richardson's (1920) data and reanalyzing it utilizing the Horton stream ordering system, the distribution of smallmouth bass in Illinois was quite predictable (Figure 9). Smallmouth bass were most common in Fourth and Fifth order streams. Third order streams appear to be transitional. A third order stream which contains smallmouth bass is in a quasi-equilibrium between two paradoxical conditions: 1) It must have enough groundwater recharge to the stream to maintain adequate pools, 2) but yet not too high groundwater recharge which would maintain water temperatures too cold for bass reproduction and growth. Conceivably, by reviewing U.S.G.S. records, many 3rd order streams could be eliminated from the sampling program (Table 10). Once the stream segments have been identified, potential sites for assessment have to be chosen. Spring Brook illustrates how the site with the largest population of bass can be determined simply by the interpretation of a topographic map. Smallmouth bass are most common in stream sections with rock-rubble

Table 10. Groundwater yield for selected streams in lower Michigan.
 (U.S.G.S. data- base-flow discharge = 7-day low-flow with 2
 year recurrence).

Stream	Order	Yield (m^3/km^2)	Dom. Sport Fish
Spring Brook	3	.001	smallmouth bass
Augusta Creek	3	.0046	brown trout
Quaker Brook	2	.0023	brown trout (marginal)
Thornapple River (Hastings)	4	.0019	smallmouth bass
Grand River (Eaton Rapids)	4	.0014	smallmouth bass
Looking Glass River	4	.0010	smallmouth bass (in high gradient sections).

substrates. The stream sections that downcut through drift accumulated the boulders and rubble. These are also the stream sections with the highest gradient.

This study illustrated that the physical aspects of the study area are determined by the physical setting of the watershed. Therefore, the watershed approach is the logical management perspective. In Spring Brook, 60% of the baseflow discharge in the research area is in the stream channel only 4 km from the source. Maintenance of this marsh is of paramount importance for sustaining summer baseflow. Spring Brook, as with many other streams in southern Michigan, is considered a county drain. The stream would have been channelized from near the source to the mouth during the 1960's had the landowners along the stream not fought adamantly to stop it. Recently, several marshes in the upper watershed have been drained and this activity will undoubtedly continue. Changes in the Inland Lakes and Stream Act should be a high priority in any management plan in lower Michigan.

Instream management for smallmouth bass appears relatively easy and inexpensive. Indications from this study and from the literature review reveal the prime objective should be the creation of pools with minimum current velocities along the periphery of the pools if spawning sites are limited. These pools should also have a rock-rubble substrate. The major factor causing the poorly developed pools in the study area was the armor-plated stream bed. This armor-plate of rubble and boulders provides excellent material for the construction of stream improvement devices. During the fall,

1977, I began construction of two devices. The basic methods outlined by White and Brynildson (1967) were followed. Modifications were based on observations and experience gained from the construction of two devices during 1965-67. No evaluation was possible at this time. Instream modification should be undertaken with great caution and should remain experimental until several questions have been answered. If the hypothesis in section IV is correct, most of the stream improvement devices currently in use favor the rockbass rather than the smallmouth bass.

In Michigan, the limited season is a management tool used for the management of smallmouth bass. The closed season is from January 1 to late May. During this study, the season opened the day the last successful nest was recorded in the study area. This is probably the worst possible situation in terms of effects on reproduction. The opening couple of weeks of the season attract by far the highest number of angler efforts. Male bass guard the nest and the fry for about 1 week and they are extremely vulnerable to angling. During the preliminary study, one male was hooked and landed on four successive casts and that fish was caught 13 times during the period of nesting and guarding the fry. The year, 1977, was also a very unusual year. It was the hottest and driest year in about 35 years. The bass usually nest in early to mid June. This indicates that during an average year the season opens just prior to the smallmouth bass's spawning period.

APPENDIX I

APPENDIX I

Flora and Fauna of the Spring Brook Study Area.

PLANTS:

Submerged:

Potamogeton pectinatus Linnaeus ; common in riffles with
open canopy

Potamogeton americanus Chamisso and Schlechtendal; common in
riffles with open canopy

Vallisneria americana Michaux; abundant; associated with silt
substrate and open canopy

Emergent:

Cephalanthus occidentalis Linnaeus: abundant along stream margin

Phalaris arundinacea Linnaeus ; common along stream margin

Sagittaria cuneata Sheldon ; common along stream margin

Saururus cernuus Linnaeus; abundant along stream margin

Iris versicolor Linnaeus ; common along stream margin

Nasturtium aquaticum Linnaeus ; abundant in limited areas
along the stream. Associated with springs.

Decodon verticillatus Linnaeus; abundant along stream margin

Polygonum hydropiperoides Michaux; common along a limited
section of the stream.

Phragmites maximus (Forster); rare along the stream margin

Sparganium eurycarpum Engelmann; common along the stream margin

APPENDIX I

Flora and Fauna of the Spring Brook Study Area.

Plants:

Sparganium chlorocarpum Rydberg; common along the stream margin

Typha angustifolia Linnaeus; rare along the stream margin

Invertebrates:

(Abundance index based on maximum number found throughout the year)

Abundant- can collect 25 or more in 10 minutes with screen

Common- can collect 10-25 in 10 minutes with a screen

Rare- can collect less than 10 in 10 minutes with a screen.

Insects

Plecoptera

<u>Acroneuria</u>	Common in rubble sections
<u>Paragnetina</u>	Common in rubble sections
<u>Perlesta</u> (probably <u>placida</u>)	Common in rubble sections
<u>Taeniopteryx</u>	Abundant- extremely abundant hatches in March and April

Ephemeroptera

<u>Isonychia</u>	Very abundant all year; associated with <u>Potamogeton</u> and gravel riffles
<u>Stenonema</u> (<u>pulchellum</u> gr)	Abundant in rubble areas
<u>Hexagenia</u> <u>atrocaudata</u>	Abundant in the stable silt beds
<u>Baetis</u>	Abundant in most habitats
<u>Ephemerella</u>	Rare in the gravel riffles

Tricoptera

<u>Pycnopsyche</u>	Abundant in most habitats
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Megaloptera

<u>Chauliodes</u>	Common in rubble areas
<u>Corydalis</u> <u>cornuta</u>	Common in rubble areas

Odonata

<u>Calopteryx</u>	Common in depositional areas
<u>Argia</u>	Common in vegetation
<u>Boyeria</u>	Common in vegetation

Hemiptera

<u>Gerris</u>	Common
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APPENDIX I

Flora and Fauna of the Spring Brook Study Area.

Crustaceans

<u>Orconectes propinquus</u>	Very abundant
<u>Cambarus</u>	Rare
<u>Gammarus</u>	Very abundant, especially in watercress.

Fishes:

<u>Ichthyomyzon fossor</u> Reighard and Cummins	Abundant
<u>Ichthyomyzon castaneus</u> Girard	Common
<u>Catostomus commersonnii commersonnii</u> (Lacepede)	Abundant
<u>Moxostoma</u> sp	Rare
<u>Hypentelium nigricans</u> (Lesueur)	Very Abundant
<u>Cyprinus carpio</u> Linnaeus	Rare
<u>Semotilus atromaculatus</u> (Mitchill)	Common
<u>Hybopsis micropogon</u> (Cope)	Abundant
<u>Notropis cornutus</u> (Mitchill)	Abundant
<u>Pimephales notatus</u> (Rafinesque)	Abundant
<u>Campostoma anomalum</u> (Rafinesque)	Rare
<u>Ictalurus melas</u> (Rafinesque)	Common
<u>Ictalurus natalis</u> (LeSueur)	Common
<u>Esox americanus vermiculatus</u> LeSueur	Common
<u>Esox lucius</u> Linnaeus	Common
<u>Percina maculata</u> (Girard)	Common
<u>Etheostoma nigrum</u> Rafinesque	Common

APPENDIX I

Flora and Fauna of the Spring Brook Study Area

Fishes:

<u>Etheostoma caeruleum</u> Storer	Abundant
<u>Micropterus dolomieu</u> Lacepede	Abundant
<u>Micropterus salmoides</u> (Lacepede)	Rare
<u>Lepomis gulosus</u> (Cuvier)	Rare
<u>Lepomis gibbosus</u> (Linnaeus)	Rare
<u>Lepomis macrochirus</u> Rafinesque	Rare
<u>Ambloplites rupestris</u> (Rafinesque)	Abundant
<u>Pomoxis nigromaculatus</u> (LeSueur)	Rare

LIST OF REFERENCES

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