THE AGE AND GROWTH OF BROWN TROUT (SALMO TRUTTA) AND SCULPIN (COTTUS SPP.) AS IT RELATES TO EUTROPHICATION IN THE JORDAN AND AUSABLE RIVERS

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ABSTRACT

THE AGE AND GROWTH OF BROWN TROUT (SALMO TRUTTA) AND SCULPIN (COTTUS SPP.) AS IT RELATES TO EUTROPHICATION IN THE JORDAN AND AUSABLE RIVERS

By

Robert F. Quick

Three sites on two rivers in Michigan were chosen to represent a gradient of eutrophication. Brown trout (Salmo trutta) were found in each site and 1,361 specimens were collected by electrofishing between March and November 1970. In the same period, 644 specimens of mottled sculpin (Cottus bairdi) were collected in the two most eutrophic sites, and 556 specimens of slimy sculpin (Cottus cognatus) were collected in the two least eutrophic sites. In streams common to both sculpin species, mottled sculpin occurred in a relative abundance ratio of 10:1 with slimy sculpin.

Brown trout were aged by scale annuli interpretation, and sculpin were aged by otolith analysis. Growth curves constructed for the seven fish populations, indicated that for every species, fish of comparable age were larger in the more eutrophic streams. Instantaneous growth rates for the populations in each species differed only in

the first year, with higher rates being exhibited by the populations in the most eutrophic environments.

The population density of brown trout was 4,395 per hectare in the least eutrophic site, and 887 per hectare in the most eutrophic, with standing crop estimates for the same fish indicating a greater biomass in the latter site. Brown trout condition (Ktl) increased during the spring to a peak in July, followed by a decrease in condition with the onset of winter. Condition of sculpin was highest in the spring and reached a low point in June, coincident with spawning activity. It was suggested by these findings that in the early stages of stream eutrophication, these species might be used to identify changes in stream degradation through corresponding changes in the growth rate of successive year classes of underyearlings.

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By

Robert F. Quick

A THESIS

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MASTER OF SCIENCE

Department of Fisheries and Wildlife

1971

to my father

the late Frank C. Quick

whom I loved and respected

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INTRODUCTION

Age and growth studies of fish populations have, in the past, been generally of a descriptive nature. However, recent interest in the problem of stream degradation has created the need to relate the results of this type of study, to the changes occurring in the aquatic environment.

Beyerle and Cooper (1960) compared three streams in Pennsylvania and found that brown trout (*Salmo trutta*) grew faster in enriched water. McFadden and Cooper (1962) found that Pennsylvania streams with high conductivity, indicating a generally fertile stream, produced larger brown trout than did streams of low conductivity. While these studies demonstrated that a higher growth rate is related to higher levels of nutrients in a stream, changes in the physical environment can also lead to changes in the growth responses of the fish population. For example, Hunt (1966) demonstrated an increase in production of wild brook trout (*Salvalinus fontinalus*) by artificial alteration of the stream channel, and Brown (1946) found that there are temperature optima for maximizing growth in two-year-old brown trout.

An example of biological factors which can affect growth is given by LeCren (1969) who noted a relationship between the growth rate of brown trout and population density. These and other factors all operate together to determine the growth rate of a fish population. Brown trout exist on a relatively high trophic level, and as such are not considered to be an accurate indicator of environmental change because physical and biological interactions operating on lower trophic levels tend to mask environmental changes before they are expressed in the fish. For the same reasons, however, the growth of these fish will not be influenced by short-term environmental variations and should, therefore, be a good indicator of the existence of long-term alterations in the stream ecology.

A three-year investigation to develop predictive indices of stream eutrophication was initiated in 1970. Data concerning water quality, aquatic macrophytes, aquatic invertebrates, and fish growth and fecundity have been collected as part of the investigation. The stream sites studied were selected to represent a gradient of eutrophication ranging from pristine to extensively perturbed.

This study was an initial part of the three-year investigation, and was concerned with the age structure and growth patterns of brown trout and sculpin in the three least perturbed stream sites. An attempt has been made to relate the growth of these fish to the level of eutrophication characterized by each study site. All of the stream data relating to this study, excluding data concerning fish, was collected by other researchers working on the three-year investigation.

DESCRIPTION OF THE STUDY SITES

The upper Jordan River station

The first site is located on the Jordan River near its source (T31N, R5W, section 31 of the Michigan P.M.) and represents unperturbed stream conditions (Figure 1). This study site has an average width of 13-16 meters, an average depth of 0.4-0.8 meters, and flow of 0.62 cubic meters per second. The stream bottom is predominantly sand and gravel and is bisected by fallen trees every few meters. These obstacles alter the stream flow, creating numerous depressions in the bottom (Figure 2). The shallow stream edges are silt covered and support dense growths of *Chara* sp. during the summer.

Water temperatures varied throughout the sampling period with an estimated maximum of 20 C in July and a recorded minimum of 3.5 C in November. Diurnal temperature differences ranged from 18 C in the spring to 2 C in the fall (Figure 3). Water quality data pertaining to the site is located in Table 1. Phosphorus levels at this site were lower than at the other study sites, while nitrogen was the highest. Dissolved oxygen levels were relatively stable throughout the summer and ranged from

Figure 1.--Jordan River showing location of collecting stations.

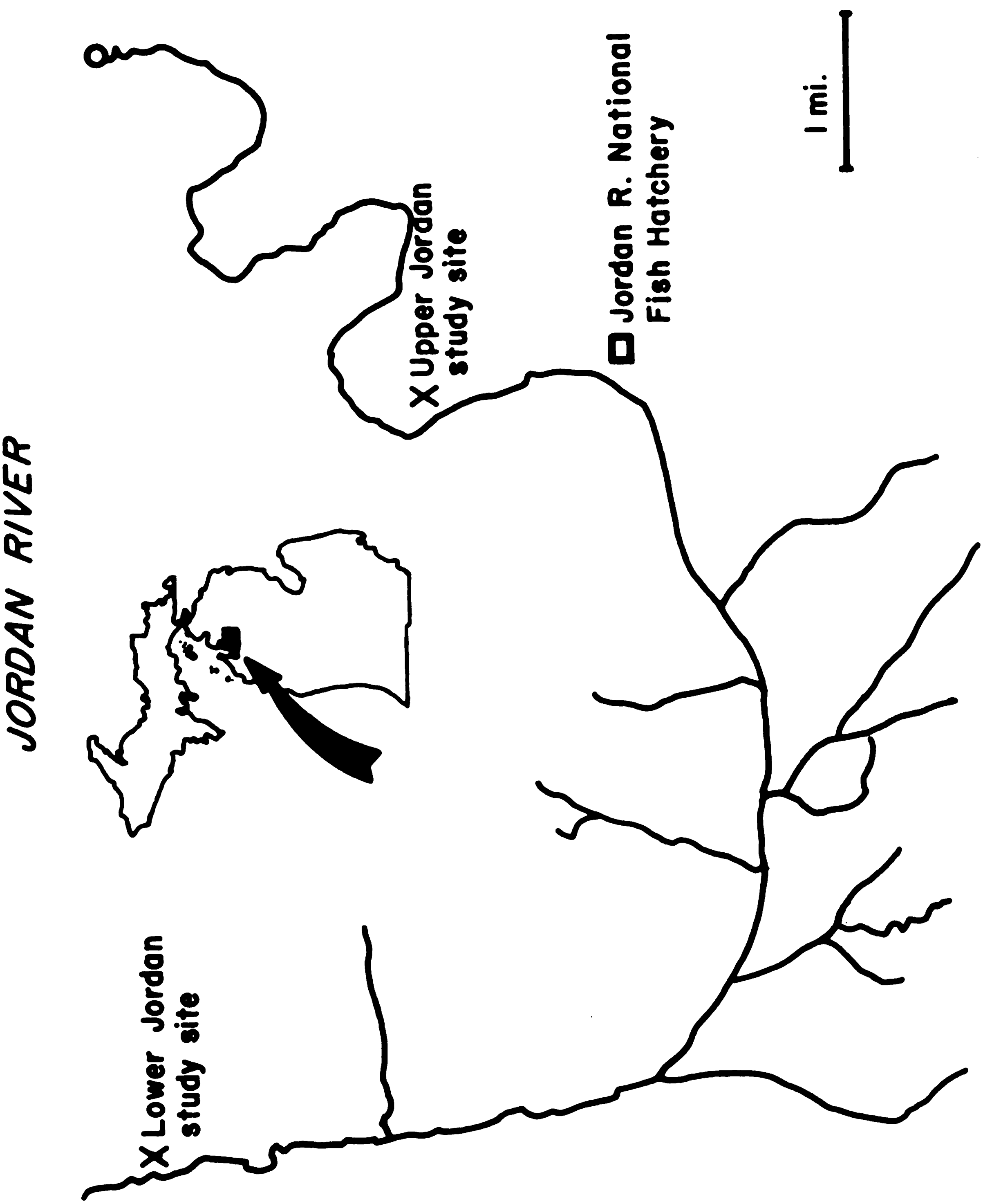

JORDAN RIVER
X Lower Jordan study site
X Upper Jordan study site
Jordan R. National Fish Hatchery
1 mi.

Figure 2.--Study site on the upper Jordan River.

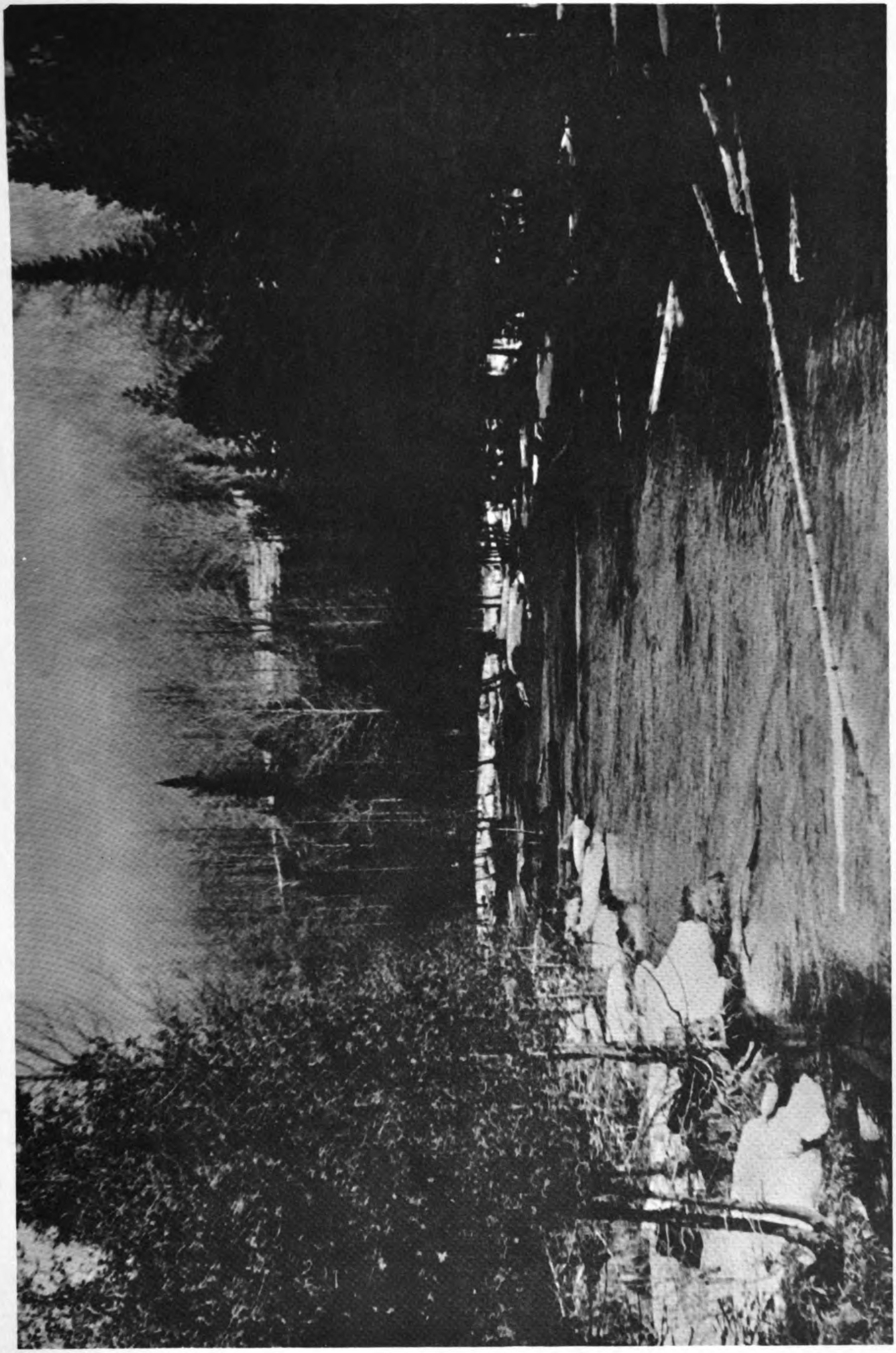


Figure 3.--Seasonal variation of water temperature in the Jordan and AuSable rivers as diurnal maxima (▲-▲), diurnal minima (O-O), or as a single midday reading (Ⓐ).

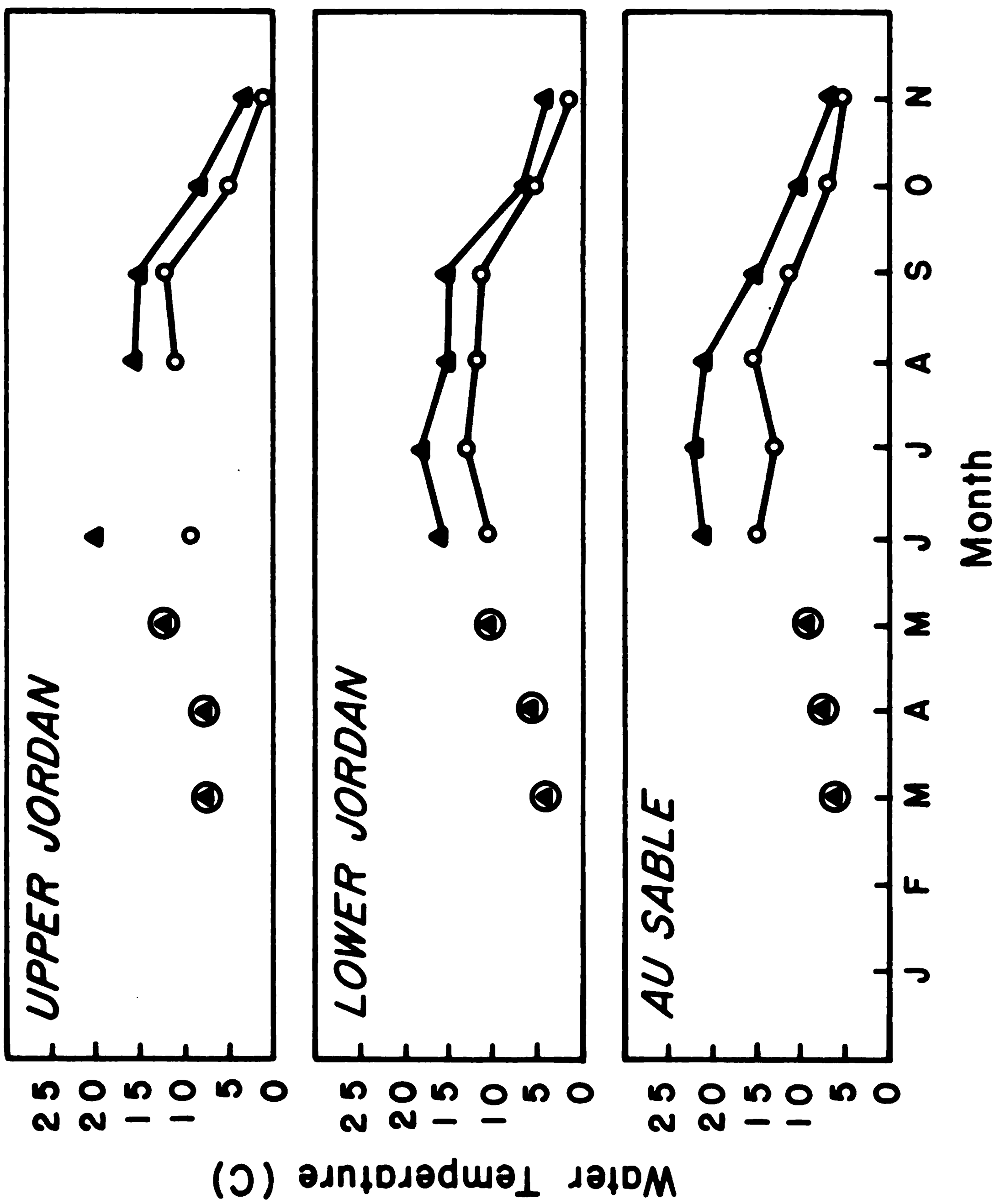

UPPER JORDAN
LOWER JORDAN
AU SABLE
Water Temperature (C)
0 5 10 15 20 25
J F M A M J J A S O N
Month

Table 1.--Physical and chemical water parameters at study sites during growing season (collected 4/12, 5/3, 5/31, 6/26, 8/11, 9/4, 9/25/70).

River	Physical (m)			Chemical (mg/liter) [average (range)]			
	width	depth					
	most freq.	most freq.	seasonal fluct.	hardness	total solids	NO_3-N	total phosphorus
Upper Jordan	13-16	0.4-0.8	0.01	182 (164-195)	199 (187-210)	0.72 (.59)-.84)	0.03 (.01-.05)
Lower Jordan	12-15	0.6-1.0	0.05	182 (171-201)	210 (198-220)	0.55 (.29-.64)	0.04 (.01-.09)
AuSable	20-25	0.5-1.0	0.13	149 (132-166)	187 (155-239)	0.10 (.06-.23)	0.05 (.03-.08)

13 to 8.4 ppm (Figure 4). The major aquatic macrophytes present were *Chara vulgaris*, *Potamogeton filiformis*, and *Elodea canadensis*.

Few fish species were encountered at this site. Slimy sculpin (*Cottus cognatus*) and brown trout comprised 50% and 30% of the March collection respectively. The remainder was composed of brook trout and rainbow trout (*Salmo gairdneri*). A single brook stickleback (*Culea inconstans*) was found early in the year. Coho salmon (*Oncorhynchus kisutch*) carcasses were observed, indicating that their spawning run from Lake Michigan had carried them to these distant reaches of the river.

The first three fish collections from this site were taken from a stream section 31 meters long. The remaining collections were taken from a 182-meter-long section which was a short distance upstream of the first location.

The lower Jordan River station

The second site is located in the lower reaches of the Jordan River (T31N, R6W, section 7 of the Michigan P.M.)(Figure 1). The site is 601 meters long with an average width of 17.4 meters, a depth of 0.6-1.0 meters, and flow of 3.54 cubic meters per second. The stream bottom is predominantly medium to coarse gravel with short stretches of sand in the center of the stream channel (Figure 5). Dense mats of *Elodea* sp. occur along

Figure 4.--Seasonal variation of dissolved oxygen in the Jordan and AuSable rivers as diurnal maxima (▲-▲) and diurnal minima (●-●).

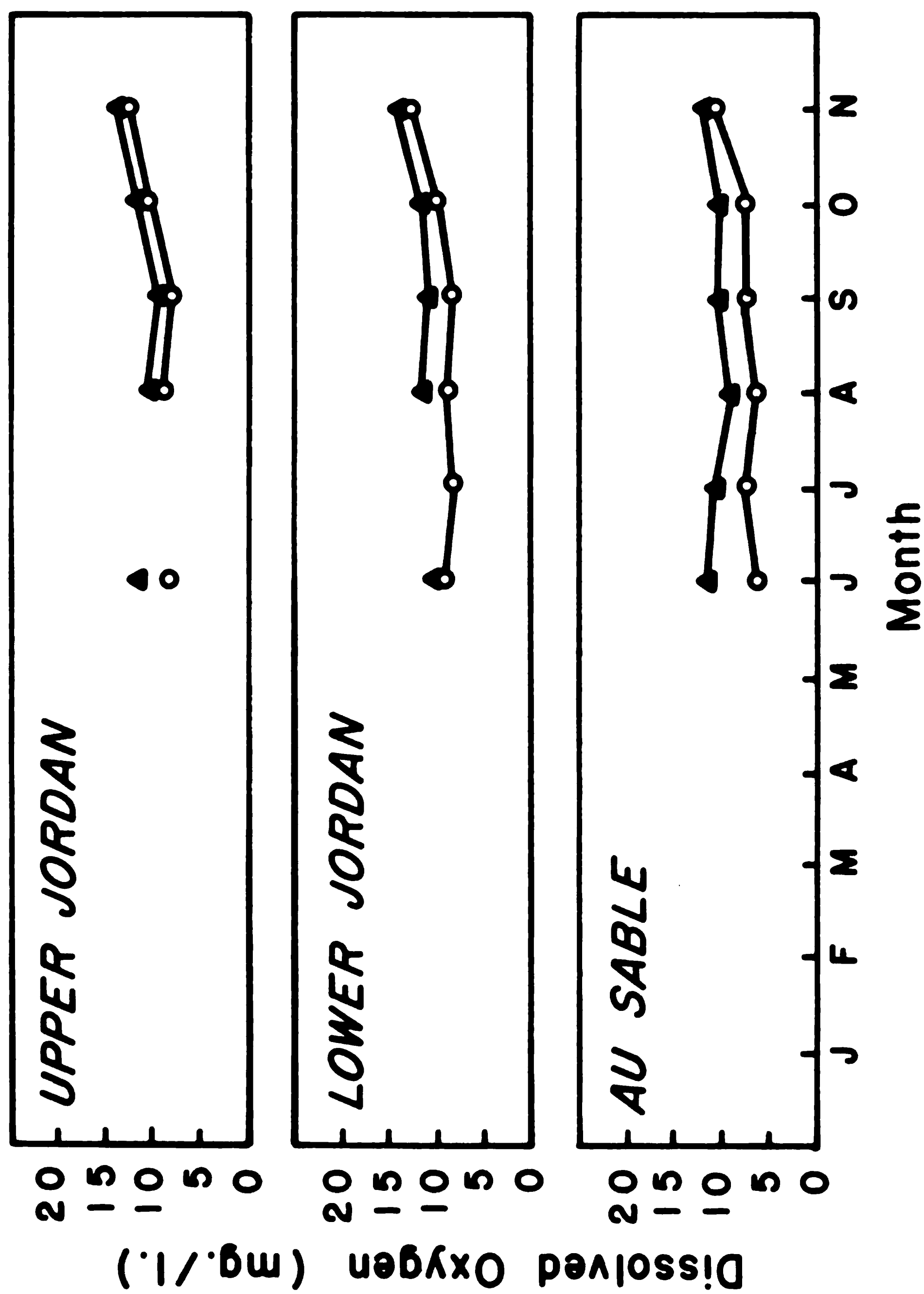
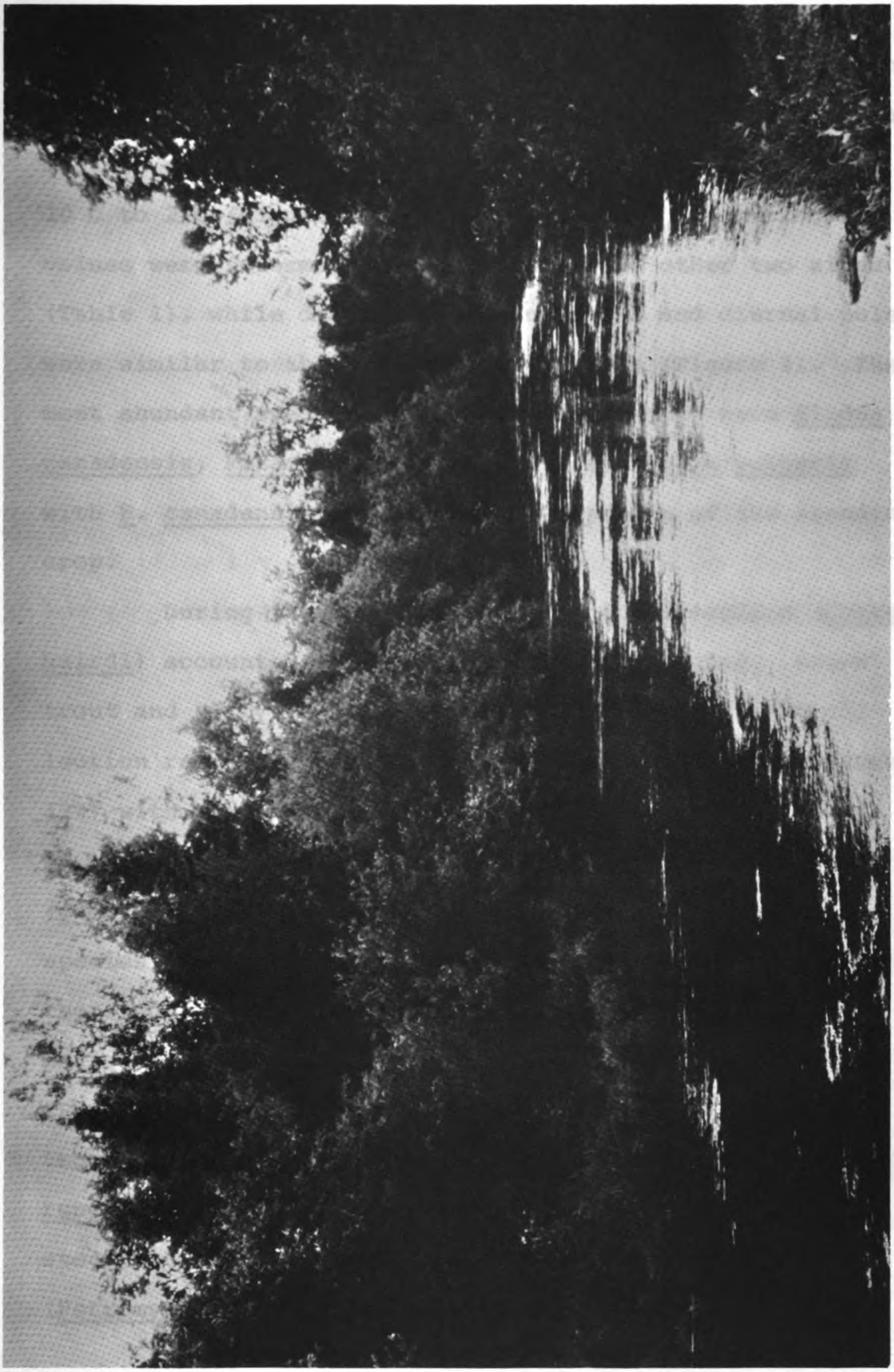

UPPER JORDAN
LOWER JORDAN
AU SABLE
20 15 10 5 0
Dissolved Oxygen (mg./l.)
J F M A M J J A S O N
Month

Figure 5.--Study site on the lower Jordan River.



the banks. Daytime water temperatures recorded during the sampling period reached a maximum of 18.5 C in July and a minimum of 5 C in November, with diurnal fluctuations of 10 C to 2 C (Figure 3). Total phosphorus and nitrogen values were intermediate to those of the other two sites (Table 1), while dissolved oxygen levels and diurnal pulses were similar to those of the other sites (Figure 4). The most abundant species of aquatic macrophytes were *Elodea canadensis*, *Potamogeten filiformis*, and *Chara vulgaris* with *E. canadensis* comprising the majority of the standing crop.

During the March sampling, mottled sculpin (*Cottus bairdi*) accounted for 75% of all fish collected. Brown trout and slimy sculpin comprised 17% and 5% of the collection respectively. Brook trout were next in abundance (3%) with the central mudminnow (*Umbra limi*) making up 1.6% of the collection. A single northern creek chub (*Semotilus atromaculatus*) was also collected, but this species was not encountered again during the remainder of the study. Many transient fish species were observed periodically throughout the year including trout-perch (*Percopsis omiscomaycus*) during June and July, rainbow trout from June through November, rock bass (*Ambloplities rupestris*) in June, and single specimens of coho salmon, steelhead trout (*Salmo gairdneri*), and sea lamprey (*Petromyzon marinus*) all apparently on spawning runs.

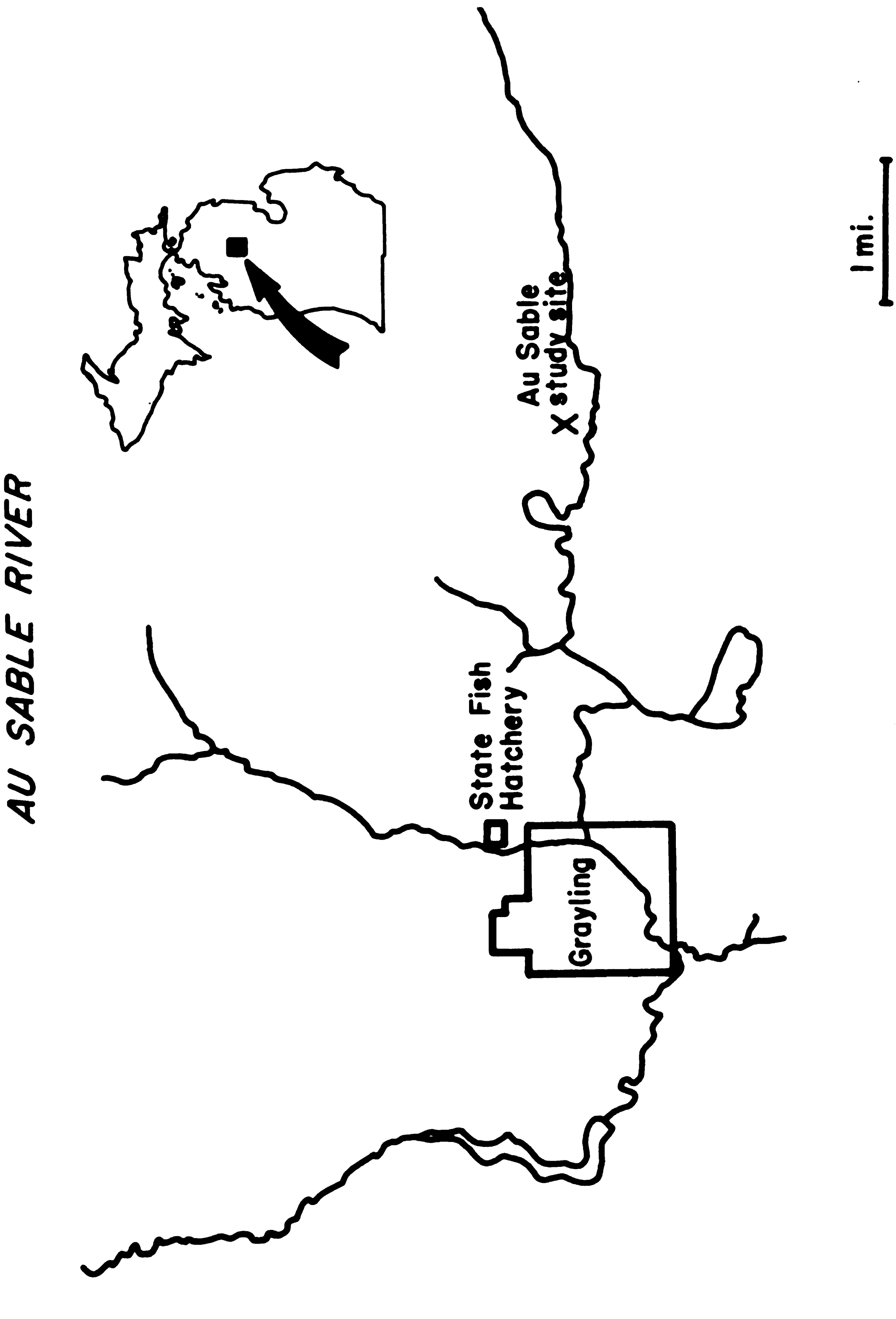
White sucker (Catostomus commersoni) were collected throughout the year but their distribution was restricted to a small pool at the lower end of the study site although a few white suckers were found throughout the site during the late summer.

Stocking records of the Michigan Department of Natural Resources indicate that none of the study sites had been stocked with fish for at least three years prior to this study. Two thousand yearling brown trout were stocked in the Jordan River in 1970, three stream kilometers below the lower Jordan River study site, but there was no indication that any of these fish reached the study site.

The AuSable River station

The AuSable River flows across the north-central portion of Michigan's lower peninsula. It is used extensively for canoeing, fishing, camping, and streamside residence. Above the study site, the river receives primary treatment sewage effluent from a community of 2000. This enrichment and other factors have created a condition of moderate pollution in the river. The study site was located 13 kilometers downstream of the community mentioned, and 171 kilometers above the mouth of the river (T26N, R3W, section 10 of the Michigan P.M.)(Figure 6). The site is 518 meters long, has a width of 20-25 meters, depth of 0.5-1.0 meters, and flow of approximately 4 cubic

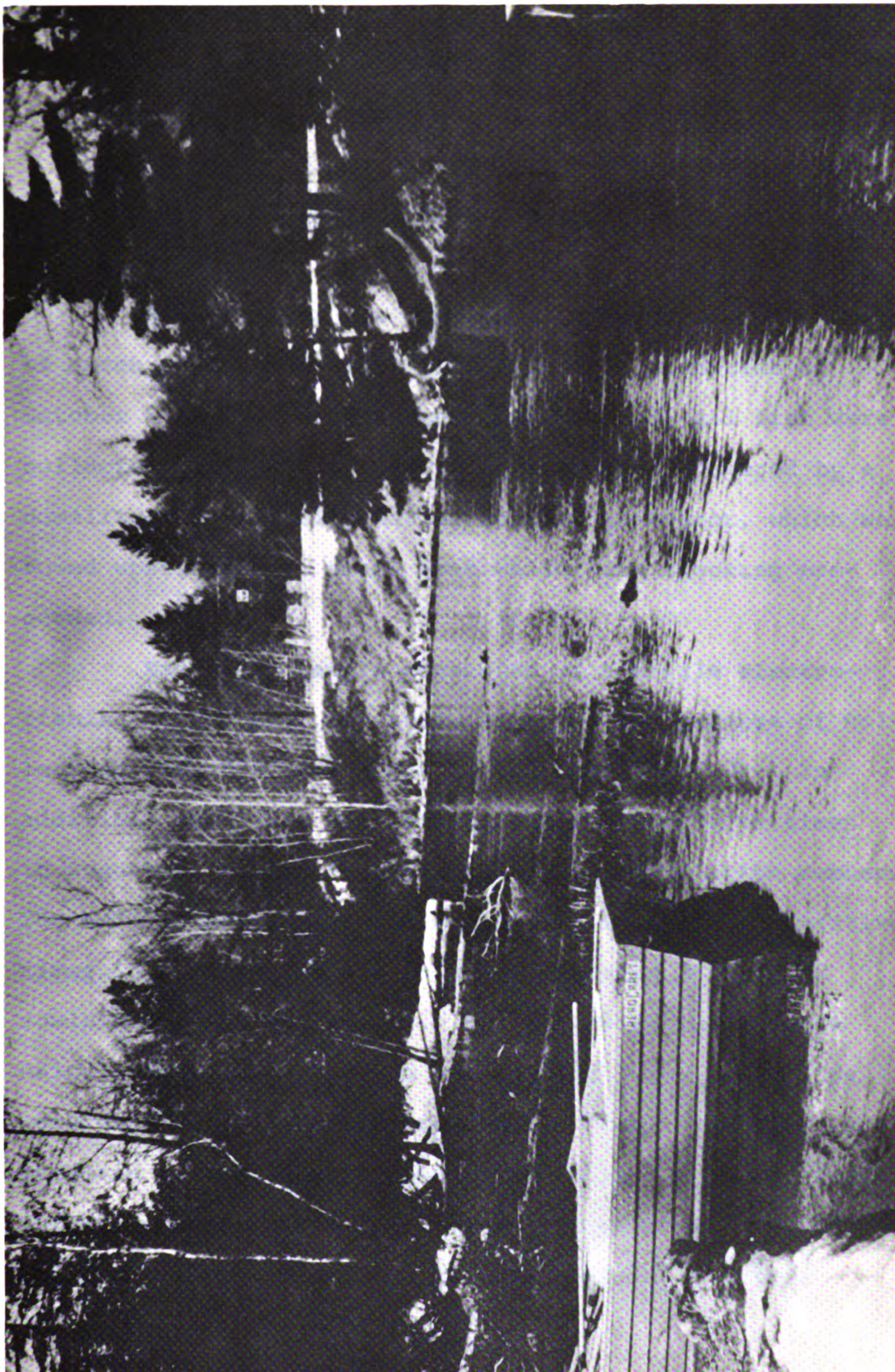
Figure 6.--AuSable River showing location of collecting station.


AU SABLE RIVER
State Fish Hatchery
Grayling
Au Sable study site
1 mi.

meters per second. The stream bottom is composed of sand with a gravel riffle 30 meters in length near the midpoint of the site (Figure 7). Water temperatures ranged from 22.2 C to 5.6 C during the sampling period, and dissolved oxygen values were similar to those observed at the other sites. Total phosphorus was the highest and nitrogen the lowest when compared to the other sites (Table 1). Potamogeton filiformis was by far, the most abundant macrophyte with P. crispus occurring less frequently. Dense beds of Potamogeton sp. developed during the summer, covering the entire stream bottom.

Mottled sculpin and brown trout were the most abundant species comprising 30% and 27% of the March fish sample respectively. Brook trout (14%) and creek chub (12%) were next in abundance while black nosed dace (Rhinichthys atratulus), white sucker, johnny darter (Etheostoma nigrum), Rainbow trout, and common shiner (Notropus cornutus) each occurred as less than 10% of the collection. The relative abundance of these fish changed in samples taken throughout the year due to the occurrence of transient fish species. The most notable was the appearance of yellow perch (Perca flavescens) and white suckers in increasing numbers as the summer progressed. Small numbers of rock bass and golden shiner (Notemigonus crysoleucas) were also encountered during the summer.

Figure 7.--Study site on the AuSable River.



MATERIALS AND METHODS

Each station was sampled monthly during the period of March 1970 to November 1970 (with the exception of October when fish samples were not taken). All fish were collected with an electrofishing apparatus, powered by a Homelite 115 volt alternating current generator, which was towed upstream in a small boat while fish shocking proceeded.

Each fish sample consisted of a single electrofishing run through the study site for the purpose of collecting fish for growth determinations (Table 2). In addition, each site was sampled three consecutive times in August to obtain an estimate of fish population numbers. The AuSable River site was again sampled three consecutive times in November to obtain a new estimate of mottled sculpin population numbers. Population estimates were calculated by the Petersen method, and dorsal fin clips were employed to identify recaptured fish. The fish in each run were aged using the appropriate age-group length intervals constructed from the interpretation of scales collected in the final run of each collection. This

Table 2.--Dates of fish sampling and numbers of each species collected.

	Dates of collection	Brown trout	Mottled sculpin	Slimy sculpin
Upper Jordan	3-25-70	34	--	57
	4-17-70*	--	--	45
	5-16-70†	44	--	--
	6-26-70	44	--	28
	7-22-70	60	--	59
	8-25-70	110	--	162
	9-21-70	106	--	79
	11-14-70	64	--	57
Lower Jordan	3-24/70	31	131	9
	4-18-70*	--	18	11
	5-16-70†	22	--	--
	6-24-70	60	29	3
	7-22-70	58	56	7
	8-24-70	71	--	24
	9-20-70	77	100	13
	11-14-70	72	60	2
AuSable	3-23-70	38	42	--
	4-16-70*	--	42	--
	5-15-70†	33	--	--
	6-23-70	44	13	--
	7-21-70	62	19	--
	8-21-70	171	37	--
	9-19-70	85	15	--
	11-12-70	75	82	--

*No attempt was made to collect brown trout on these dates.

†Sculpin were collected on these dates but deteriorated during storage and were not included in calculations.

allowed a separate population estimate to be made for each age-group of a species.

Captured fish were measured to the nearest millimeter total length and weighed to the nearest gram. A minimum of twenty brown trout scales were removed from an area on the fish below the anterior edge of the dorsal fin at a point midway between the dorsal fin and the lateral line. The scales were impressed on acetate slides using a roller press without heat. This method distorts the scale impression slightly, but the distortion is constant at all points on the impression, resulting in a minimal bias to calculations derived from observations of scale annuli location (Butler and Smith, 1953). The scale impressions were magnified to 44 diameters on a Baush and Lomb scale projector and antero-lateral scale radii and annuli locations were recorded.

Since the sculpin were to be aged by otolith examination, they were not returned to the stream after capture, but were placed in 40% formalin and after 24 hours were transferred to 40% alcohol for storage. The sculpin were dissected by making a transverse cut through the head from a point behind the skull to the posterior edges of the opercular spines to gain access to the paired otoliths (Figure 8). These were removed with forceps, cleaned of connective tissue, and stored in glycerine. The otoliths became translucent within 24 hours revealing opaque banding. After this clearing

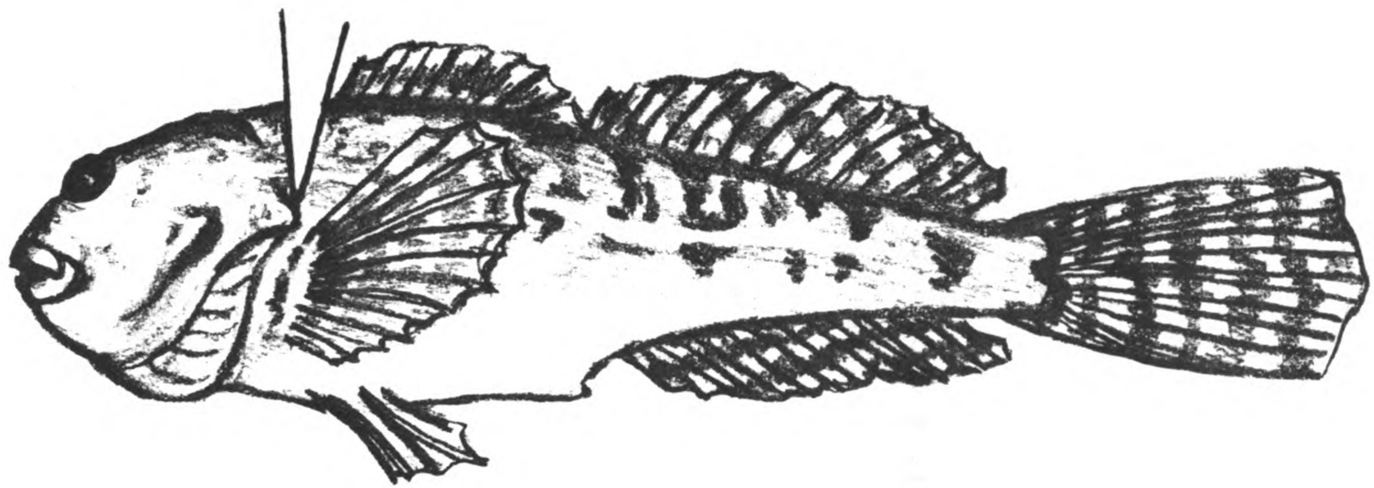


Figure 8.--Adult sculpin showing point of incision in preparation for otolith removal.

process, the otoliths were magnified to 40 diameters on a dissecting microscope and observed under indirect lighting. The radius was measured on the concave side of the otolith from the central core to the most distant lateral edge. The annuli appeared as thin, transparent lines located more distant from the core than the thick opaque bands representing the previous spring growth (Bailey, 1952).

Age and growth data for all species was calculated by computer with a program developed by Hogman (1969). The program was modified to permit the use of length-weight information from fish which had not been aged.

RESULTS

PART I--BROWN TROUT

Length-scale relationship

As described previously, total scale radius was recorded for most of the brown trout collected. When these values were plotted against the length of the fish from which the scale had been taken, a linear relationship resulted of the form:

$$Y = a + bX$$

where Y = total length in millimeters, a = the intercept value on the total length axis, b = the slope of the regression line, and X = the scale radius in millimeters (x 44). Some species of fish may have length-scale relationships which are slightly curved (Ricker, 1958). This was not true in the brown trout populations studied. Correlation coefficients for the equations ranged from .90 to .95, indicating a nearly perfect fit with the data (Table 3).

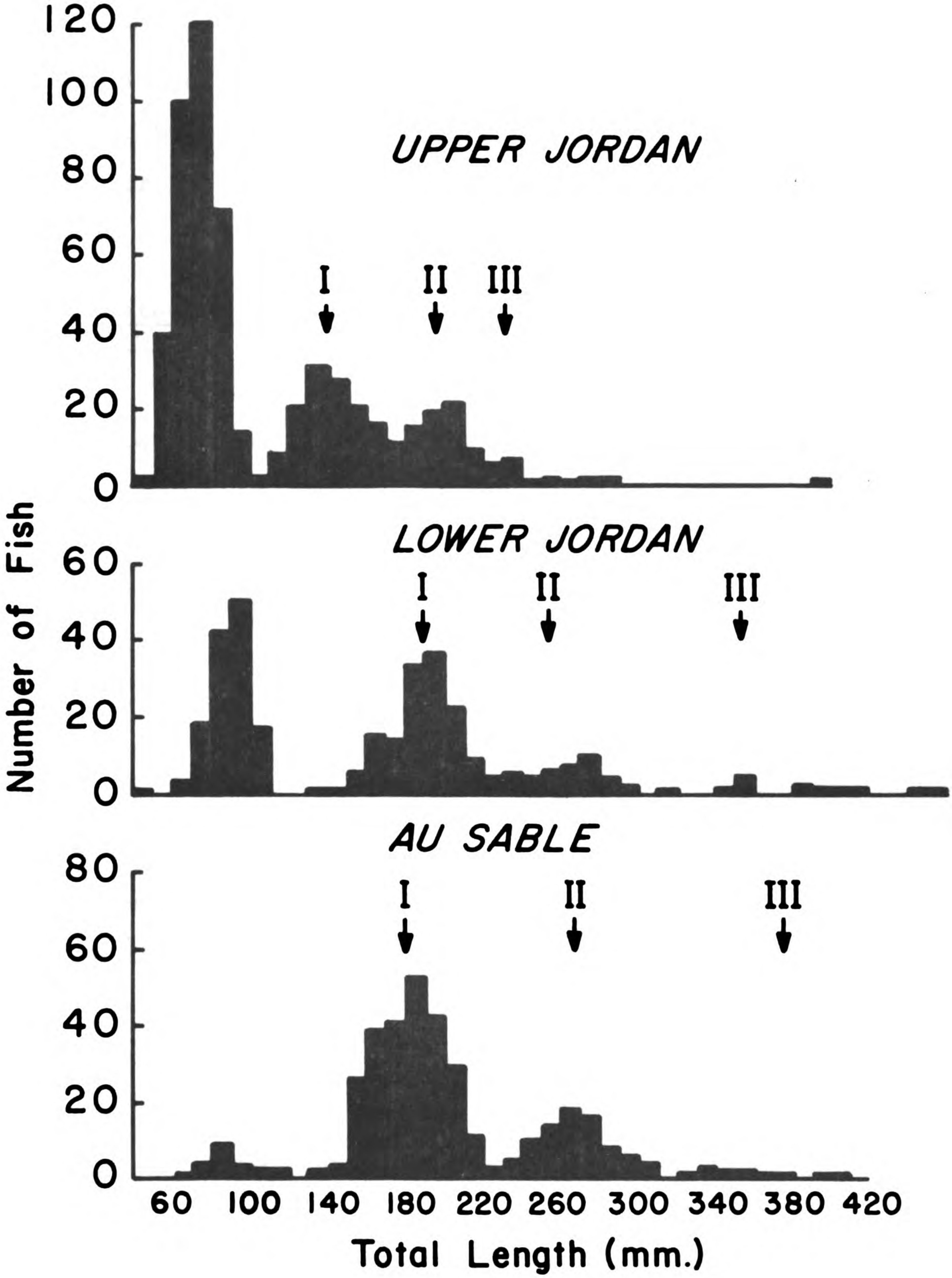
Table 3.--Length-scale regressions and correlation coefficients for brown trout in the Jordan and AuSable rivers.

Sampling site	Length-scale relationship	Correlation coefficient
Upper Jordan	Y = 20.51 + 4.3158X	.899
Lower Jordan	Y = 14.87 + 4.4978X	.948
AuSable	Y = 23.85 + 4.5026X	.901

Length-frequency relationship

Histograms of the length-frequency of brown trout were constructed from data collected during August and are based on a minimum of 322 individuals per site (Figure 9). The modes of the histograms were assumed to represent the distribution of lengths in a given age-group based on reasoning given by Tesch (1968). The mean length at capture for each age-group is also indicated. In each histogram, the calculated lengths for age-groups 0 through 3 are indicated and coincide with the distributional modes. Unregenerated scales could not be found for a number of fish over 220 mm long in the upper Jordan collection. Therefore the mean length at capture for age-group 3 seems to be biased downward in comparison with the modes of the histogram for that population. The mean length at capture of age-group 3 brown trout in the upper Jordan River during July, August, and September, when averaged, indicate that in August the mean length of age-group 3 lies closer

Figure 9.--Length frequency distribution of brown trout in the Jordan and AuSable rivers for fall 1970. Roman numerals designate age-groups. Fish were grouped by 10 mm intervals of total length.


UPPER JORDAN
LOWER JORDAN
AU SABLE
I
II
III
I
II
III
I
II
III
120
100
80
60
40
20
0
60
40
20
0
80
60
40
20
0
Number of Fish
60 100 140 180 220 260 300 340 380 420
Total Length (mm.)

to 240 mm. This value fits the distributional mode for age-group 3 more closely. Since the modes of the histograms approximate the average length of each age-group as derived by the scale aging technique, it can be concluded that for this study, this method of aging brown trout was valid.

Calculated length at annulus formation

The total length of a fish at the time of annulus formation was calculated from the Lee-Lea equation:

$$L_n = a + \frac{(L_t - a)}{S_t} S_n$$

where L_n = the length of the fish at annulus n, L_t = the total length of the fish at capture, a = the total length intercept of the body-scale equation, S_n = scale radius at annulus n, and S_t = total scale radius at capture (Hogman, 1969). The mean length at the time of annulus formation for every year class, and a weighted mean length at annulus formation for the population as a whole was calculated (Tables 4 through 6 and Figure 10). The reliability of the calculated lengths for age-group 4 fish was reduced because few fish of this age group were collected.

The resultant growth curves were compared at the first three annuli to determine if significant differences existed in growth between the three populations. An analysis of variance test was conducted for each comparison

Table 4.--Total length at each age of brown trout from the upper Jordan River. Numbers in parentheses indicate sample size.

Age group	Calculated length at annulus formation (mm)					Average TL at capture
	1	2	3	4	5	
I	77.5(225)					141.7
II	79.8(146)	165.2				199.0
III	67.9 (32)	157.1	218.2			239.0
IV	73.4 (3)	164.6	232.5	277.4		301.7
Weighted means	77.1(406)	162.8(181)	219.4(35)	277.4(3)		
Increment	77.1	85.7	56.6	58.0		

Table 5.--Total length at each age of brown trout from the Lower Jordan River. Numbers in parentheses indicate sample size.

Age group	Calculated length at annulus formation (mm)					Average TL at capture
	1	2	3	4	5	
I	111.5(189)					180.7
II	97.5(113)	215.9				256.9
III	96.1 (27)	219.6	326.4			362.2
IV	88.4 (7)	217.2	322.9	421.4		440.4
V	91.6 (4)	230.5	321.6	417.9	483.5	524.5
Weighted means	105.0(340)	217.0(151)	325.3(38)	420.1(11)	483.5(4)	
Increment	105.0	120.3	105.0	97.8	65.5	

Table 6.--Total length at each age for brown trout from the AuSable River. Numbers in parentheses indicate sample size.

Age group	Calculated length at annulus formation (mm)					Average TL at capture
	1	2	3	4	5	
I	120.2(277)					181.6
II	121.8(145)	229.4				262.3
III	125.8 (29)	237.9	311.4			334.2
IV	132.9 (5)	241.8	311.5	378.4		395.4
Weighted means	121.2(456)	231.1(179)	311.4(34)	378.4(5)		
Increment	121.2	108.3	73.0	66.9		

Figure 10.--Mean annual increments of growth for brown trout in the Jordan and AuSable rivers. Vertical lines represent 95% confidence limits of the mean.

and in every case a significant difference was indicated (P=.01). This means that at each of the selected points on the growth curves, at least two of the three populations exhibited lengths which were significantly different. Kramer's modification to Duncan's New Multiple Range Test was employed to more accurately determine which pairs of growth curves were different (Kramer, 1956). This modification allows comparison of mean values which are derived from unequal sample sizes. The mean length at each annulus for each population was significantly different (P=.01) with the exception of the lower Jordan and AuSable rivers brown trout at the second annulus. This was expected since growth curves for the two populations intersect during the third year of life.

Based on the data just given, it is assumed that growth of brown trout in the upper Jordan River was restricted in comparison to the other two populations. It is difficult to make a similar statement about the relative growth of the brown trout in the lower Jordan and AuSable rivers since the AuSable population is initially the more rapidly growing of the two but becomes subordinate in growth to the lower Jordan brown trout after the second year.

"Lee's phenomenon" is said to occur when the length at a particular annulus appears to be less when calculated from older fish, than when it is calculated from younger fish (Lee, 1912). This has been observed previously in brown trout length calculations by Ball and Jones (1960), and a list of possible causes of this phenomenon is given by Tesch (1968). Lee's phenomenon occurred in the length calculations for lower Jordan trout, and a reversal of this phenomenon was exhibited in the length calculations for the AuSable trout population. The occurrence of this phenomenon in lower Jordan brown trout length calculations suggests that the actual lengths might be higher for young trout and lower for older trout than was calculated. Similarly, the reversal of Lee's phenomenon in length calculations for AuSable brown trout indicates that the actual lengths may be lower for young fish and higher for older fish than was calculated. If this is true, then the growth curves of the lower Jordan and AuSable brown trout differ less than is now indicated. Length calculations for the upper Jordan brown trout population did not exhibit Lee's phenomenon.

Instantaneous rate of growth

The instantaneous growth rate (or specific growth rate) is described by the general formula:

$$G = \frac{\log_e Y_t - \log_e Y_o}{t}$$

where G = the instantaneous rate of growth, Y_t = the length at the end of the period, Y_o = the length at the start of the period, and t = the time interval between Y_t and Y_o (Tesch, 1968).

By choosing "t" to be one year, Y_t and Y_o can be the estimate of length at two consecutive annuli. An estimate of the length of fry in the swim-up stage was necessary to determine the instantaneous growth rate dur- the first year. Beyerle and Cooper (1960) determined the average length of brown trout fry as 23 mm when they leave the redd. In Pennsylvania, brown trout are 25 mm long when the yolk sac is absorbed (Ball and Jones, 1962). The length of fish in age-group 0 used in growth rate calculations by Frost (1945) is 24 mm. The latter value was assumed to be the length of age-group 0 fish in the present study. The instantaneous growth rates calculated for the brown trout populations in this study are presented in Figure 11. All three populations had the highest growth rates as young fish and the AuSable River young grew the fastest of the three populations of young. In later years, however, this is reversed with the AuSable River brown trout growing at a rate equal to or slightly less than that of the other two trout populations. There was little difference in instantaneous growth rates between populations of brown trout in the older age groups, regardless of the rate of growth of young.

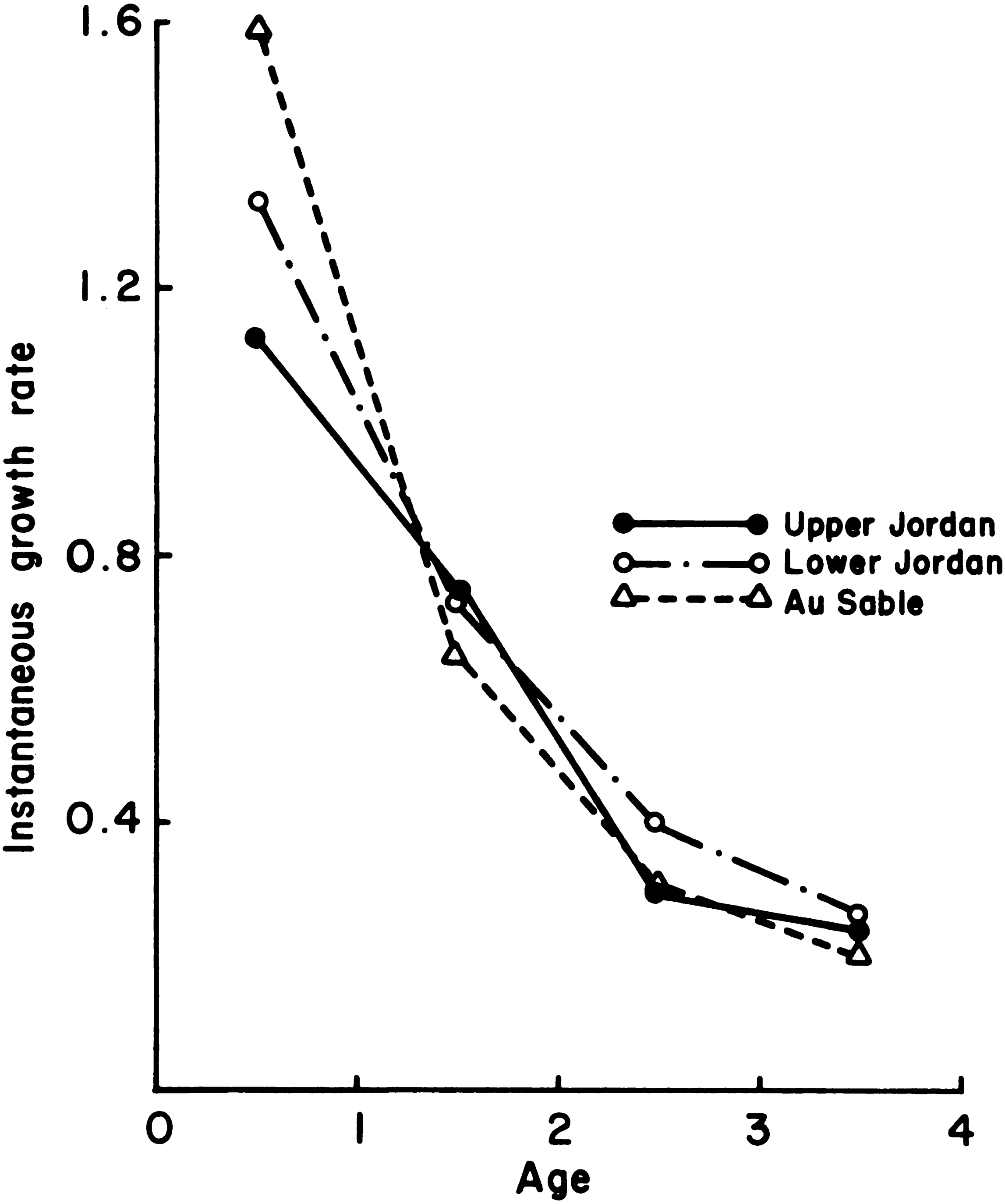


Figure 11.--Instantaneous rate of growth for each year, of brown trout in the Jordan and AuSable rivers for 1970.

Length-weight relationship

The expression:

$$\log W = \log a + (b)(\log TL)$$

was used to describe the relation of fish length to weight where W = weight in grams, TL = total length in millimeters, and a = the intercept value on the length axis (Carlander, 1969). "b" is almost always between 2 and 4, and is typically close to 3 for salmonids (Lagler, 1956). Determination of the correlation between length and weight was not attempted and is usually considered unnecessary (Tesch, 1968). The length-weight equations were determined from the combined monthly collections to minimize the effects of growth stanzas and seasonal condition encountered in calculations which are based on a single large sample (Beyerle and Cooper, 1960)(Table 7).

Table 7.--Length-weight regressions of brown trout in the Jordan and AuSable rivers.

Sampling site	Length-weight regression
Upper Jordan	log W = -4.9227 + 2.9641 logTL
Lower Jordan	log W = -4.7720 + 2.8981 logTL
AuSable	log W = -4.8556 + 2.9309 logTL

The length-weight regressions were almost identical for all three populations and are similar to the regression; log W = -4.908 + 2.96 log TL which was determined for brown trout in the Pigeon River in Michigan (Cooper and Benson, 1951).

The weight of the brown trout at the time of annulus formation was determined from the lengths calculated for the same period, using the appropriate length-weight regression (Table 8).

Table 8.--Calculated weight at annulus formation of brown trout in the AuSable and Jordan rivers.

Site	Sample size	Calculated weight at annulus formation (grams)				
		1	2	3	4	5
Upper Jordan	407	4	43	106	299	
Lower Jordan	340	12	99	322	677	1017
AuSable	456	17	118	283	501	

The differences in weight between populations reflected the differences in lengths between populations because the calculated lengths were used to compute weight.

Population density and age structure

Population densities were estimated by the Petersen method of mark and recapture and extrapolated to an area of one hectare (Lagler, 1956). The Petersen method is based on the following assumptions: (1) marked fish retain identifying marks throughout the study period, (2) marked fish are evenly redistributed throughout the population, (3) marked and unmarked fish are equally susceptible to subsequent capture, and (4) immigration or emigration does not occur (Robson and Reiger, 1968). Criteria of the first assumption are met by the short-term nature of the sampling. The fourth assumption includes the requirement that mortality of marked fish is not greater than unmarked fish. Brynildson and Brynildson (1967) have shown that marking by fin clip does not introduce appreciable mortality, and Bouck and Ball (1966) have shown that mortality due to electroshocking is minimal under most conditions. The second and third assumptions could have been violated because a maximum period of 24 hours separated the collections, and this may not have been sufficient time for marked fish to recover and be re-distributed in the population. If these two assumptions were violated, then the population estimates have been biased upwards. This bias should have negligible effect on the use of the estimates as a means of comparing populations between sites since the time intervals used for population estimate sampling were the same at each site, resulting in an approximately equal bias to all estimates.

The fish caught in the first and subsequent sampling runs of the estimate were assigned ages according to the length-age relationship of the population. This relationship was constructed from age determinations of fish in the final sample run. An estimate of the size of each age-group was then computed using the Peterson formula. In the upper Jordan River site, brown trout density exceeded 4,000 fish per hectare compared to 699 per hectare in the lower Jordan and 887 per hectare in the AuSable River (Table 9). While the upper Jordan brown

Table 9.--Estimated number per site (± 1 SE) and number and weight per hectare of brown trout at three study sites in August 1970.

Site	Age	Number of fish per site (± 1 SE)	Number of fish per hectare	Kilograms of fish per hectare
Upper Jordan River	0	616±51.13	3075	12.3
	I	150±12.45	750	18.8
	II	96± 2.98	480	36.0
	III	17± 6.77	85	10.8
Lower Jordan River	0	218±26.60	335	3.0
	I	166±10.46	255	17.3
	II	57± 5.10	78	12.0
	III	20± 9.70	31	12.1
	IV	--	--	--
	V	2± 0.0	3	2.8
AuSable River	0	42±17.68	69	0.6
	I	358±25.06	587	35.2
	II	141±17.20	231	43.2

trout maintained more than four times the population density of the AuSable River brown trout, the upper Jordan brown trout exhibited a smaller standing crop in biomass because the majority of fish in the upper Jordan population were underyearlings which did not contribute greatly to the total weight of the population.

Brown trout of age-groups 3 and 4 in the AuSable River, and of age-group 4 in both Jordan sites were absent from the August fish sample and were not included in the population estimate. However, small numbers of fish in these age-groups were collected in other monthly samples.

There was an inordinately small number of young-of-the-year fish in the AuSable brown trout population. It would seem reasonable that sampling efficiency was not responsible for this apparent lack of young fish since bias of this type would not affect the population estimate as long as it was consistent for each sampling run, an assumption which is acceptable. If the age-group 0 estimate is valid, two possible causes for its small size would be: (1) the study site will not support large numbers of young fish, or (2) recruitment was greatly restricted during 1970 only. If recruitment is consistently low, then a high rate of immigration of yearlings would be necessary to maintain the observed population structure. This does not seem likely since brown trout over 150 mm long do not tend to emigrate from their home range (Mense, 1970). In addition, high population densities have been assumed to be the chief cause of transients in a brown trout population (Jenkins, 1969). Yearling brown trout in the AuSable River, attained the greatest length at the first annulus of any trout population of which I have knowledge. It is unlikely that these fish could grow as well their first year, in the presence of the high population density necessary to cause their emigration to the study site. The alternative cause of a small population of young fish, that recruitment was restricted for the 1970 year class only, can not be proven without determining the numbers of young brown trout in the AuSable River in subsequent years. Regardless of how they entered the population, the AuSable brown trout did grow rapidly, and had maintained the largest standing crop in biomass of the trout populations studied.

Condition

Condition factors of 1- and 2-year-old brown trout, were determined for the months of May, June, July, September, and November of 1970. The condition factor (Ktl) is a measure of the relative well-being of a fish, and is calculated from the equation:

$$Ktl = \frac{W \times 10^5}{L^3}$$

where W = weight in grams and L = total length in millimeters. The constant 10^5 is used to bring the values near unity (Carlander, 1969).

The condition of both age groups tended to increase during the spring to a peak in July, and then declined progressively through the remainder of the sampling period (Figures 12 and 13). The same trends in condition were noted for brown trout in Spruce Creek, Pennsylvania (Beyerle and Cooper, 1960).

The condition of yearling brown trout was greater than that of two-year-old trout in each population reflecting a trend towards decreased condition with age. A similar tendency has been noted by other investigators (Ball and Jones, 1960 and Kathrein, 1951). Upper Jordan yearling brown trout had a higher condition early in the year, than did yearlings in the other two brown trout populations studied, but all exhibited the same condition by the end of the summer. When comparing the condition of populations at a given length, as would be the case between two-year-old upper Jordan brown trout (Figure 13), and yearling trout in the lower Jordan and AuSable rivers (Figure 12), the upper Jordan trout exhibit a consistently lower condition throughout the year than do the other two brown trout populations. Since age and length both affect condition in fish, to compare these three trout populations at the same age and length might necessitate comparing populations at different seasons, which would introduce yet another bias to the comparison. Obviously comparing fish populations by their respective condition factors is possible only when they exhibit the same growth rate throughout life, enabling fish of the same length, and age to be compared at the same season.

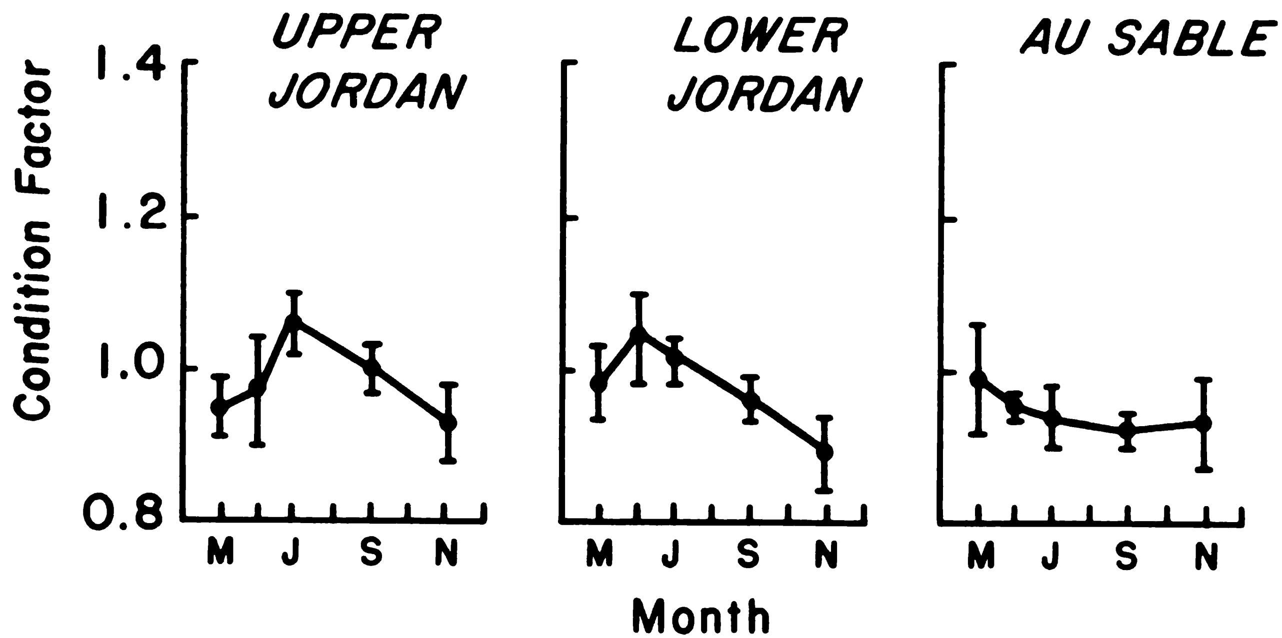


Figure 12.--Changes in mean condition (K) of yearling brown trout in the Jordan and AuSable rivers during 1970. Vertical lines represent 95% confidence limits of the mean.

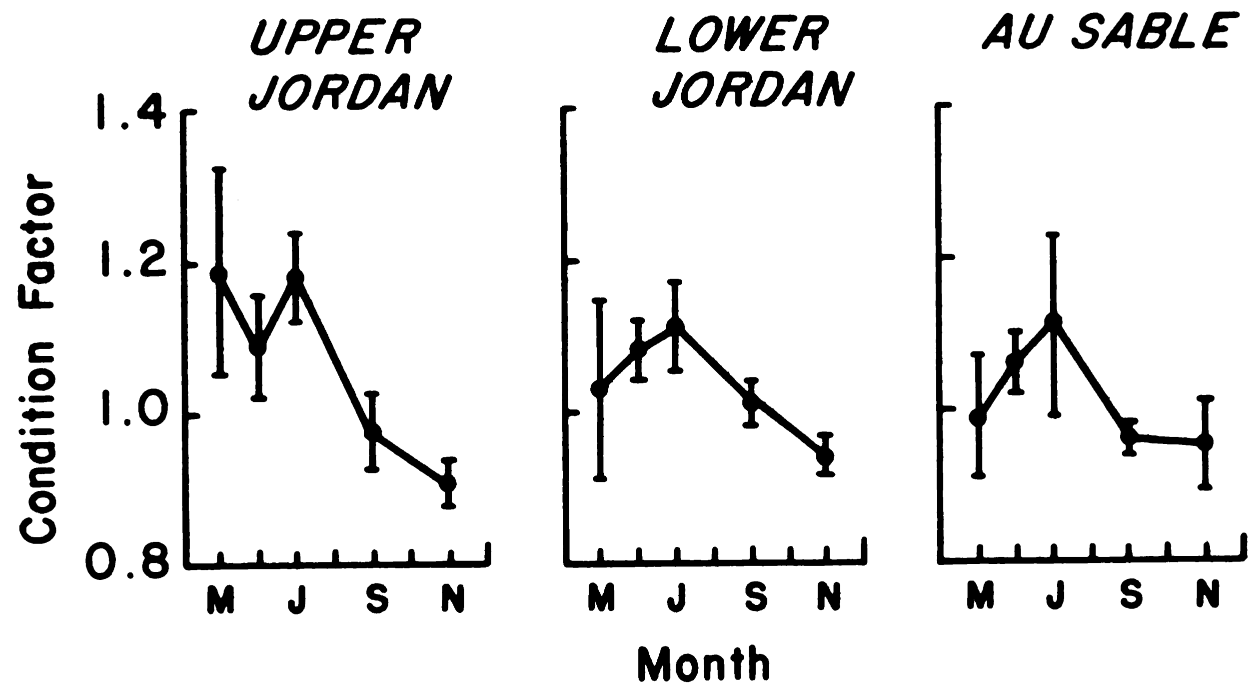


Figure 13.--Changes in mean condition (K) of two-year-old brown trout in the Jordan and AuSable rivers during 1970. Vertical lines represent 95% confidence limits of the mean.

RESULTS

PART II--SCULPIN

Length-otolith relationship

An otolith radius was determined for each sculpin collected and the relationship between total length and otolith radius was ascertained from the general formula:

$$Y = a + bX$$

where Y = the total length in millimeters, a = the intercept value on the total length axis, b = the slope of the regression line, and X = the otolith radius in millimeters (x 40) (Table 10).

Length-frequency relationship

The length-age distributions of the four sculpin populations demonstrate an extreme overlap of lengths between members of adjoining age-groups older than one year (Table 11). This overlap tends to mask the distributional modes of the length-frequency histograms for these populations of sculpin (Figure 14). However, the large sample from which upper Jordan River slimy sculpin length frequency histogram was made, does show distinct modes representing the first three age-groups, and the calculated

Table 10.--Length-otolith relationship of two species of sculpin in the Jordan and AuSable rivers with related correlation coefficients.

Species	Study site	Length-otolith relationship	Correlation coefficient
Slimy sculpin	Upper Jordan	$Y = -2.39 + 1.1614X$	.928
Slimy sculpin	Lower Jordan	$Y = 4.14 + 1.1321X$	.904
Mottled sculpin	Lower Jordan	$Y = -3.71 + 1.1245X$	.954
Mottled sculpin	AuSable	$Y = -2.12 + 1.1674X$	.913

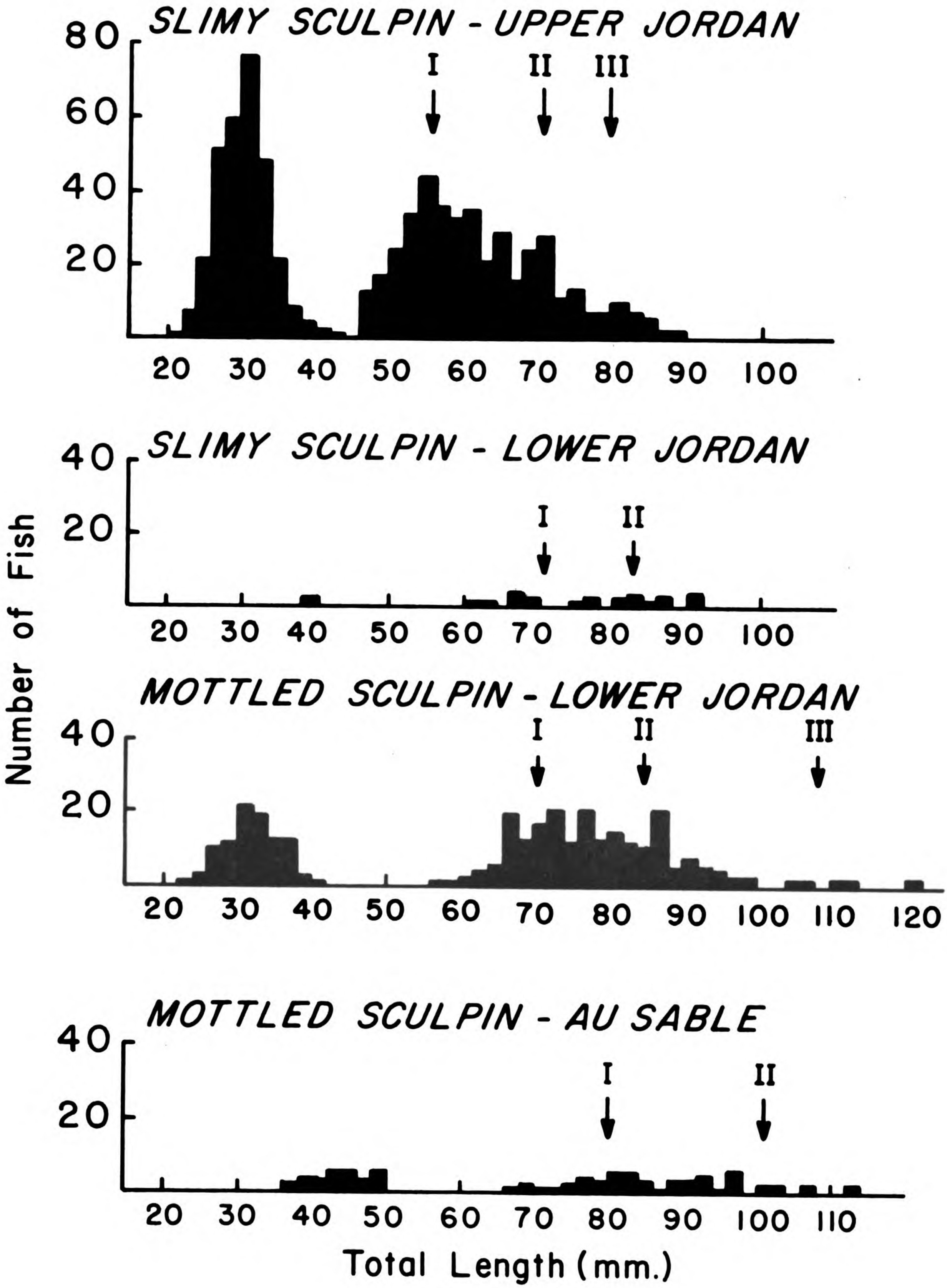
Table 11.--Age distribution for two species of sculpin from the Jordan and AuSable rivers in successive 5 mm intervals of total length.

Interval of total length (mm)	Slimy sculpin							
	Upper Jordan age group				Lower Jordan age group			
	0	I	II	III	0	I	II	III
25-29	1							
30-34	10							
35-39	28							
40-44	12							
45-49	1							
50-54		10			1			
55-59		9						
60-64		16	1					
65-69		16	1			1		
70-74		9	6			3		
75-79		3	5	1		2		
80-84			2	1		0	1	
85-89			1	1		3	1	
90-94							1	
95-99								1

Table 11.--Continued.

Interval of total length (mm)	Mottled Sculpin							
	Lower Jordan age group				AuSable age group			
	0	I	II	III	0	I	II	III
25-29	0							
30-34	3							
35-39	27							
40-44	18							
45-49	7				3			
50-54	1				8			
55-59	1				14	4		
60-64					3	8		
65-69		6			0	10		
70-74		10			1	7		
75-79		16				8		
80-84		6	5			6		
85-89		3	5			5	4	
90-94			10			1	1	
95-99			5			0	4	
100-104			3			0	6	1
105-109			1	1		1	2	1
110-114				2				
115-119				0				
120-124				1				

Figure 14.--Length-frequency distribution of two species of sculpin in the Jordan and AuSable rivers for August 1970. Roman numerals designate age-groups. Fish were grouped by 2 mm intervals of total length.


SLIMY SCULPIN - UPPER JORDAN
80
60
40
20
I
II
III
20 30 40 50 60 70 80 90 100
SLIMY SCULPIN - LOWER JORDAN
40
20
I
II
20 30 40 50 60 70 80 90 100
MOTTLED SCULPIN - LOWER JORDAN
40
20
I
II
III
20 30 40 50 60 70 80 90 100 110 120
MOTTLED SCULPIN - AU SABLE
40
20
I
II
20 30 40 50 60 70 80 90 100 110
Number of Fish
Total Length (mm.)

lengths for these age-groups agree closely with the modal peaks. It was assumed that a similar reliability extends to age determinations for the remaining three sculpin populations. Ludwig and Norden (1969) found wide ranges of lengths within age-groups of mottled sculpin in Wisconsin and length-frequency histograms of 899 mottled sculpin in the West Gallatin River, Montana did not show clearly defined modes for fish two years old and older (Bailey, 1952). This indicates that sculpin do not grow significantly in length after the third year.

Calculated length at annulus formation

The lengths at annulus formation of each age-group for the slimy sculpin populations are given in Tables 12 and 13, and for the mottled sculpin populations in Tables 14 and 15. The weighted mean lengths at annulus formation calculated for each population are presented in Table 16.

Student's t test was used to compare the calculated lengths between populations of each species at each of the first three annuli (Mendenhall, 1967). The results of the six "t" tests indicated that a significant difference (P=.05) existed between the calculated lengths of the two populations of slimy sculpin and between the two populations of mottled sculpin, at the first three annuli. The calculated lengths of slimy sculpin in Valley Creek, Minnesota collected during January, 1970 were close to the

Table 12.--Total length at each age for slimy sculpin from the upper Jordan River. Numbers in parentheses indicate sample size.

Age group	Calculated length at annulus formation (mm)					Average TL at capture
	1	2	3	4	5	
I	32.0(207)					55.1
II	35.1(106)	58.1				71.8
III	34.3 (23)	56.1	76.0			83.3
IV	35.2 (8)	61.8	79.5	91.9		94.6
Weighted means	33.2(344)	58.0(137)	76.9(31)	91.9(8)		
Increment	33.2	23.1	19.3	12.4		

Table 13.--Total length at each age for slimy sculpin from the lower Jordan River. Numbers in parentheses indicate sample size.

Age group	Calculated length at annulus formation (mm)					Average TL at capture
	1	2	3	4	5	
I	45.0(41)					66.6
II	47.2(14)	71.0				83.1
III	42.0 (6)	70.5	92.1			96.5
IV	38.7 (1)	59.7	77.4	105.0		105.0
Weighted means	45.1(62)	70.3(21)	90.0(7)	105.0(1)		
Increment	45.1	25.1	21.0	27.6		

Table 14.--Total length at each age for mottled sculpin from the lower Jordan River. Numbers in parentheses indicate sample size.

Age group	Calculated length at annulus formation (mm)					Average TL at capture
	1	2	3	4	5	
I	40.4(230)					67.4
II	38.7(254)	71.9				82.3
III	39.6 (20)	70.2	95.6			105.2
IV	38.0 (6)	55.8	70.9	87.8		111.5
Weighted means	39.5(510)	71.4(280)	89.9(26)	87.8(6)		
Increment	39.5	31.9	18.5			

Table 15.--Total length of each age for mottled sculpin from the AuSable River. Numbers in parentheses indicate sample size.

Age group	Calculated length at annulus formation (mm)					Average TL at capture
	1	2	3	4	5	
I	48.6(134)					72.3
II	49.0 (44)	84.7				97.6
III	42.2 (14)	77.0	103.6			107.6
IV	51.3 (1)	80.9	94.0	102.3		126.0
Weighted means	48.3(193)	82.8(59)	102.9(15)	102.3(1)		
Increment	48.3	35.4	25.7			

Table 16.--Calculated mean lengths at annulus formation for four populations of sculpin in the Jordan and AuSable rivers (± 1 SE).

Species	Study site	Calculated length at annulus formation			
		1	2	3	4
Slimy sculpin	Upper Jordan	33.2±0.71	58.0±0.41	76.9±1.57	91.9
Slimy sculpin	Lower Jordan	45.1±0.69	70.3±1.60	90.0±2.97	105.0
Mottled sculpin	Lower Jordan	39.5±0.27	71.4±0.46	89.9±2.04	87.8
Mottled sculpin	AuSable	48.3±0.47	82.8±1.35	102.9±3.25	102.3

lengths calculated at the first four annuli of slimy sculpin in the lower Jordan River (C. E. Petrosky, unpublished data). Detailed descriptions of sculpin growth were not found in the literature, but a February length-frequency histogram for mottled sculpin in a Utah stream yielded average lengths for age-groups 1 through 4 which were similar to the growth of lower Jordan mottled sculpin (Zarbock, 1952).

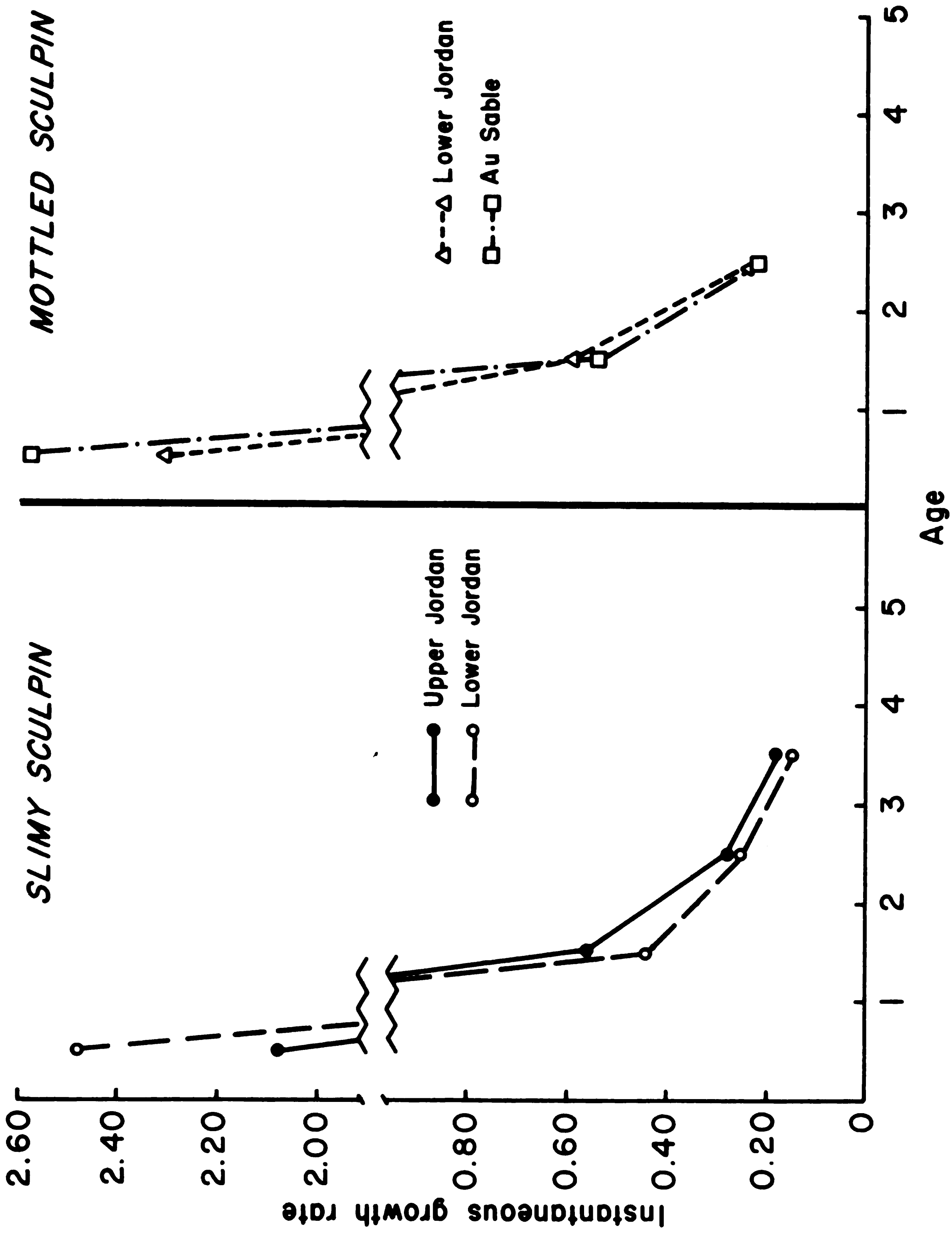
In this study, the faster growing populations in each species were located in the more eutrophic stream site, and in the lower Jordan River where the two sculpin species co-existed, the mottled sculpin grew faster than did the slimy sculpin.

Instantaneous growth rate

Instantaneous growth rates of the type described previously for brown trout were calculated for each sculpin population (Figure 15). The growth rate of the 1970 year class was based on an estimated initial length of 7 mm. This is approximately the length reported by Ludwig and Norden (1969) and Bailey (1952) for mottled sculpin fry at the time they leave the nest.

Each sculpin population exhibited a growth rate which was maximum in the first year, and which decreased sharply in later years. In each species, the population of sculpin which contained the most rapidly growing young was located in the more eutrophic stream.

Figure 15.--Instantaneous rate of growth for each year of two species of sculpin in the Jordan and AuSable rivers for 1970.


SLIMY SCULPIN
MOTTLED SCULPIN
Upper Jordan
Lower Jordan
Lower Jordan
Au Sable
Instantaneous growth rate
2.60
2.40
2.20
2.00
0.80
0.60
0.40
0.20
0
1
2
3
4
5
Age

Length-weight relationship

The length-weight regressions of the faster growing populations in both sculpin species, had a much lower slope than did the slower growing populations, indicating that at a given length, the more rapidly growing populations exhibited a greater weight than did the slower growing ones (Table 17 and Figure 16).

The relationship of length to weight for mottled sculpin in a Montana stream was determined to be log W = -4.798 + 3.161 log TL (Bailey, 1952). This is similar to length-weight regressions for mottled sculpin in the AuSable River and slimy sculpin in the Lower Jordan River. The weight of sculpin at annulus formation was determined from the length-weight relationships given in Table 18.

These calculated weights are only approximate estimates since the sculpin were weighed to the nearest gram, a coarse unit of measure for an organism of this size.

Population density

Population estimates of the four sculpin populations were only partially reliable. There were an estimated 4,271 slimy sculpin in the upper Jordan River study site (SE ± 652) which represents a density of 85,045 fish per hectare. The combined population of both sculpin species in the lower Jordan River study site was estimated to be 4,787 (SE ± 749). The relative abundance ratio of

Table 17.--Length-weight relationships of two species of sculpin in the Jordan and AuSable rivers.

Species	Study site	Length-weight regression
Slimy sculpin	Upper Jordan	$\log W = -3.3910 + 2.1754 \log TL$
Slimy sculpin	Lower Jordan	$\log W = -4.9451 + 3.0616 \log TL$
Mottled sculpin	Lower Jordan	$\log W = -3.4337 + 2.2279 \log TL$
Mottled sculpin	AuSable	$\log W = -5.2841 + 3.2413 \log TL$

Figure 16.--Length-weight relationship. Logarithmic plot of mean weight against mean length for two species of sculpin from the Jordan and AuSable rivers.

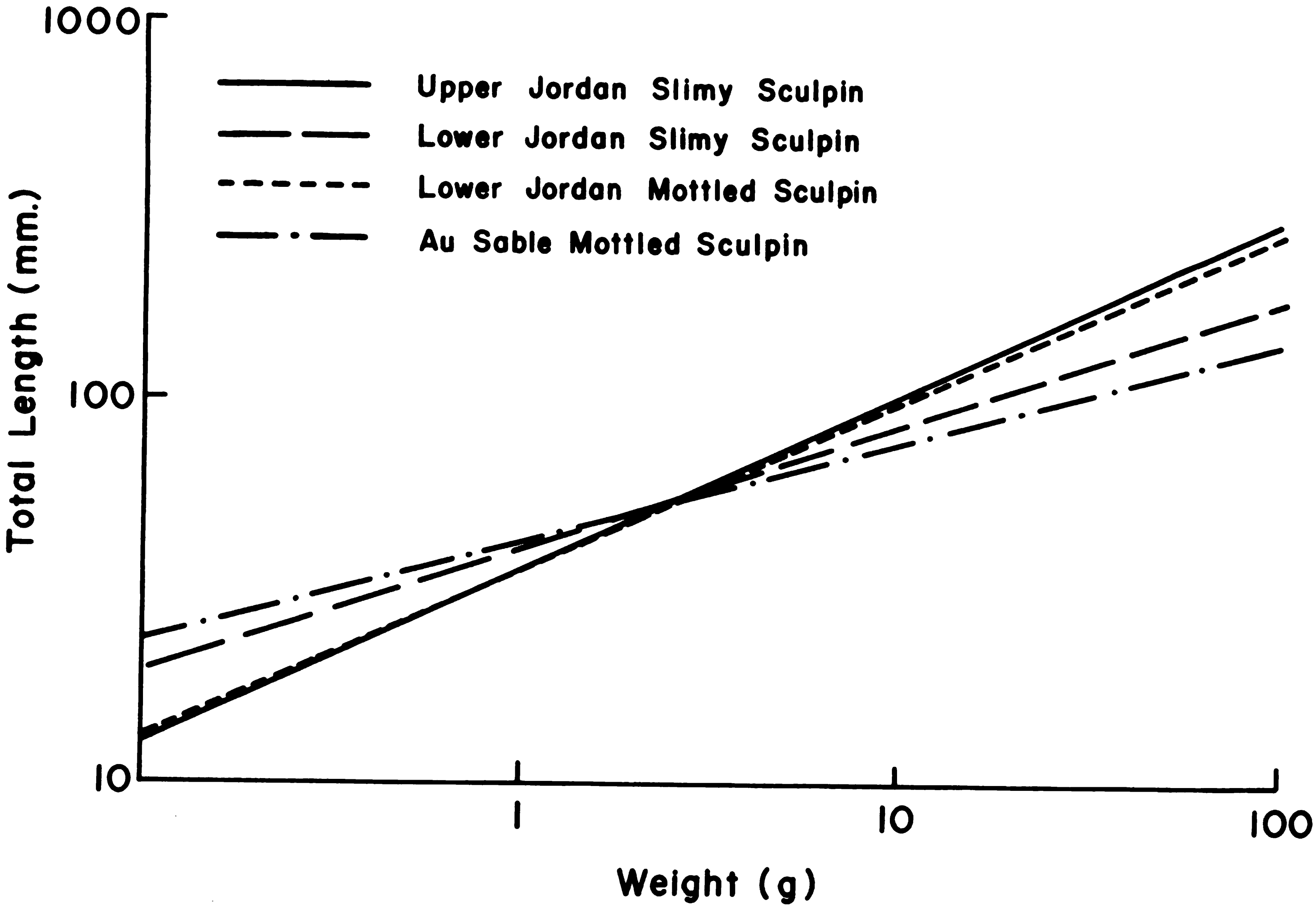

Upper Jordan Slimy Sculpin
Lower Jordan Slimy Sculpin
Lower Jordan Mottled Sculpin
Au Sable Mottled Sculpin
Total Length (mm.)
1000
100
10
1
10
100
Weight (g)

Table 18.--Calculated weight (gm) at annulus formation for two species of sculpin in the Jordan and AuSable rivers.

Species	Study site	N	Calculated weight at annulus formation			
			1	2	3	4
Slimy sculpin	Upper Jordan	344	<1	2	5	7
Slimy sculpin	Lower Jordan	62	1	5	10	17
Mottled sculpin	Lower Jordan	510	1	6	8	--
Mottled sculpin	AuSable	193	1	8	17	16

mottled sculpin to slimy sculpin in this site was 10:1 in the total collection. The same ratio was used to apportion population estimates to the species. This resulted in an estimated density of 6,758 and 589 fish per hectare for mottled sculpin and slimy sculpin respectively. There were an estimated 4,608 mottled sculpin in the AuSable River site (SE ± 2,488); a density of 5,915 sculpin per hectare. While this estimate is of low reliability, it does indicate that the density of mottled sculpin is lower in the AuSable River, than in the lower Jordan River. This same density relationship was observed between the two sites during the sampling operations at the study sites. The slower growing populations of each species, the upper Jordan slimy sculpin and the lower Jordan mottled sculpin, exhibited the highest population densities for their species.

Condition

The sculpin on the three study sites, appeared to reach peak spawning activity in early May. Hann (1927) reported that mottled sculpin in Michigan spawn during late April and Ludwig and Norden (1969) found that in Wisconsin, this species spawned during the entire month of April with a peak activity near the middle of the month. A significant decline in condition occurred in each sculpin population during this period (Figures 17 and 18). Spawning does not appear to be the only possible

Figure 17.--Changes in mean condition (K) of two species of yearling sculpin in the Jordan and AuSable rivers during 1970. Vertical lines represent 95% confidence limits of the mean.

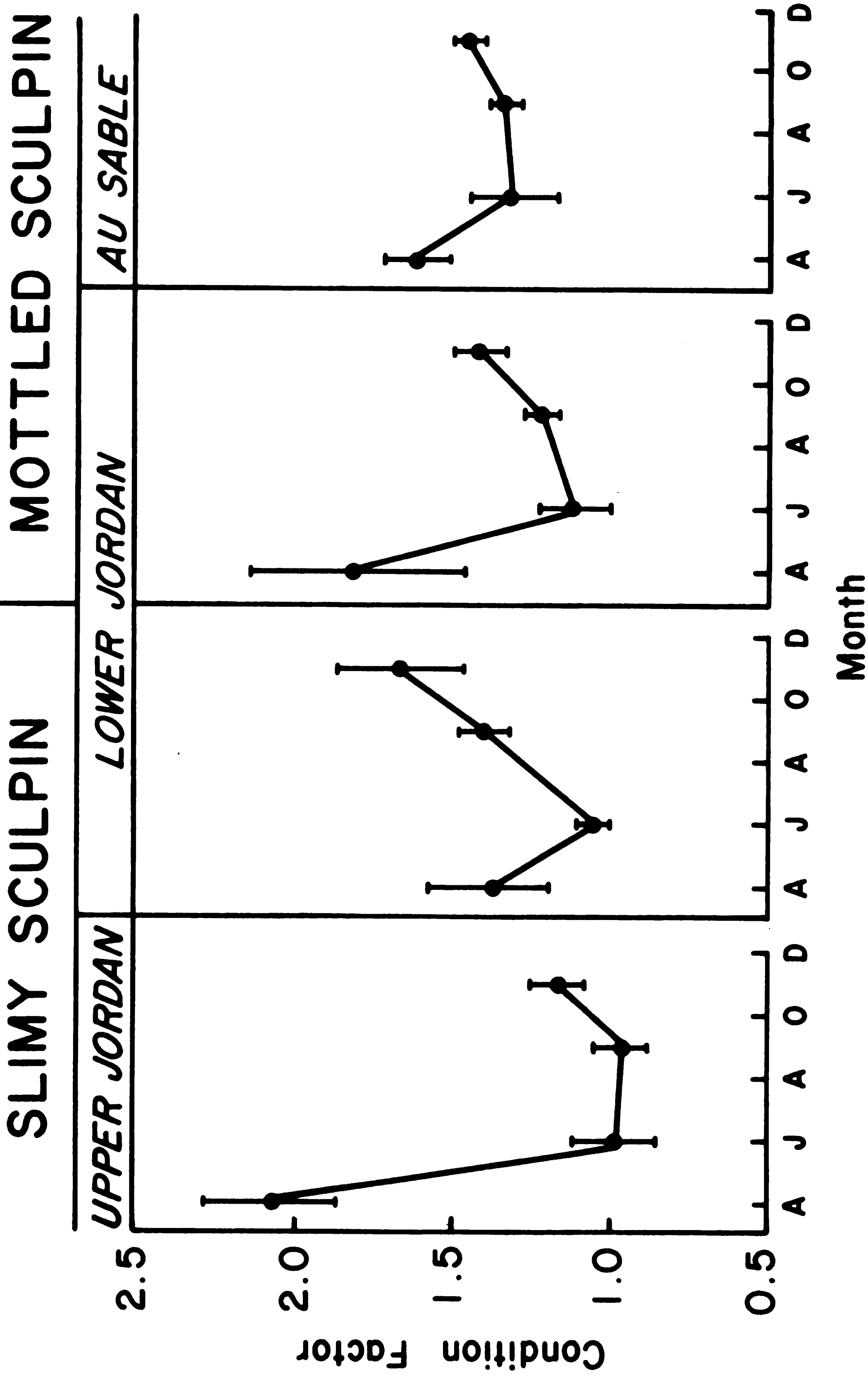
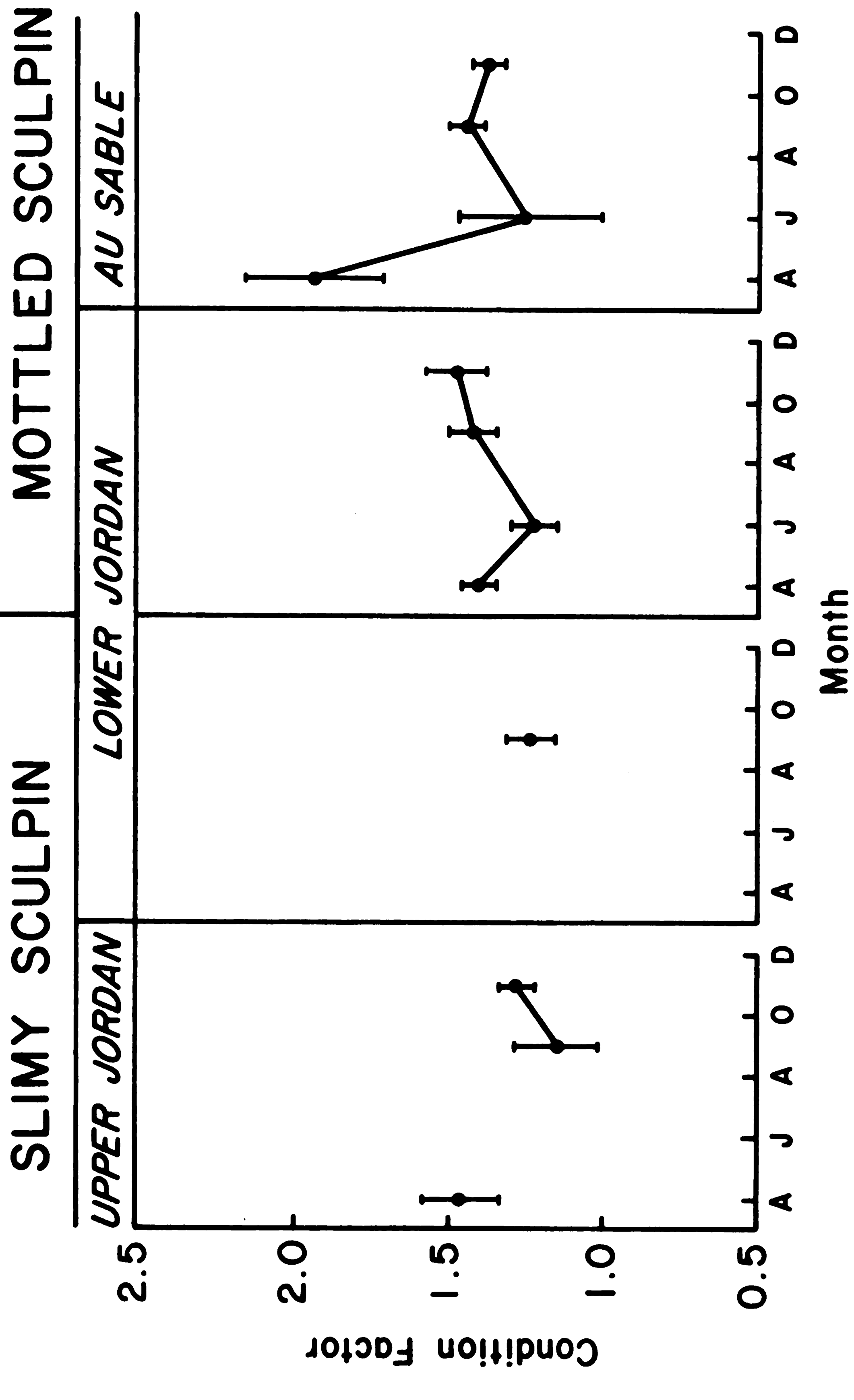

SLIMY SCULPIN
MOTTLED SCULPIN
UPPER JORDAN
LOWER JORDAN
AU SABLE
Condition Factor
2.5
2.0
1.5
1.0
0.5
A J A O D
A J A O D
A J A O D
Month

Figure 18.--Changes in mean condition (K) of two species of two-year-old sculpin in the Jordan and AuSable rivers during 1970. Vertical lines represent 95% confidence limits of the mean.


SLIMY SCULPIN
MOTTLED SCULPIN
UPPER JORDAN
LOWER JORDAN
AU SABLE
Condition Factor
2.5
2.0
1.5
1.0
0.5
A J A O D
A J A O D
A J A O D
A J A O D
Month

cause of a reduced condition since the same trends are apparent in yearling sculpin which did not spawn in that year. The peak condition occurs early in the spring, with another minor peak in the fall. Since sculpin were not collected in the winter, it cannot be ascertained if there are two peaks in condition annually or if sculpin maintain a high condition throughout the winter. Zarbock (1952) reported that condition of mottled sculpin increased with increases in length up to 55 mm standard length, after which condition decreased, and that these Ksl values were near 3.0 which is much higher than was calculated for sculpin in this study.

The condition of age-group 1 sculpin was higher than that of age-group 2 during April, but two-year-old sculpin exhibited higher condition than yearlings after the spawning season.

DISCUSSION

The growth of brown trout has been related to a multitude of physiological and environmental factors, including, the natural fertility of the water (McFadden and Cooper, 1962), the quality and quantity of food available (Ellis and Gowing, 1957), temperature (Purkett, 1951 and Swift, 1955, 1961), respiration (Fry, 1968), pH of the water (Frost, 1945), competition (McFadden and Cooper, 1962), and the presence of helminth parasites on the fish (Thomas, 1964). It is likely that these internal and external factors act collectively upon the fish's genetic potential for growth. It has been the aim of this study to relate the growth of three fish species to the early stages of stream eutrophication.

A river does not become eutrophic in the same sense that a lake does, but the term "eutrophic" can be applied to moving water to indicate the constant additions of nutrients to the water and the resultant changes in the aquatic ecosystem. The most basic of these changes would be an increase in primary production which in turn would create additional food and cover for many consumer species in the summer months. The increased primary production would also alter the level of dissolved oxygen and increase diurnal dissolved oxygen fluctuations. The increase in primary production would be reflected in corresponding qualitative and quantitative increases at all consumer trophic levels. These changes alone could account for a greater growth of fish in the more eutrophic environments by increasing the available food for the fish. At the same time, successive stages of eutrophication appear to be related to increases in the number of fish species which intensifies competition for food and predation. Coupled with competition for nesting sites, this could account for a reduction in population numbers of a given species.

At some higher level of eutrophication one would expect to find mature fish growing at a maximum rate, coupled with a minimal population size and further increases in eutrophication would result in a lack of spawning success and the species would be removed from the community.

Water temperatures differed between the study sites and may have been responsible for some of the differences in fish growth. Brown (1957) and Swift (1961) have shown that there are temperature optima for which brown trout growth is maximized and these optimal temperatures were found to exist in the more eutrophic sites.

The three stream sites in this study were assumed to represent the early stages of stream eutrophication where the upper Jordan, lower Jordan, and AuSable rivers represented pristine, minimally perturbed and moderately perturbed stream conditions respectively.

Brown trout grew slower in the upper Jordan River than in either of the other two study sites. This was coupled with a high population density, due primarily to an abundance of young trout. Although the biomass of the upper Jordan brown trout population approached that of the brown trout in the AuSable River, the most eutrophic site, the average weight per individual was low as a result of the preponderance of young fish in the population.

The mechanisms responsible for this growth and density pattern were not identified, but were probably a combination of a paucity of available food coupled with a high rate of recruitment of young fish. It is possible that larger, faster growing brown trout had been produced in the upper Jordan River, and that they migrated out of the study area due to a lack of suitable food, cover, or inappropriate water temperatures but this is unlikely since the density of mature brown trout in the upper Jordan River far exceeded that of brown trout in the other study sites.

It was expected that the growth of brown trout would be greater in the AuSable River than in the lower Jordan River, yet this relationship did not hold for mature brown trout. One cause for this seeming discrepancy has been given as the occurrence of "Lee's phenomenon" in length calculations. It is also possible that calculated lengths of mature brown trout in the lower Jordan River were biased upwards by the inclusion of data from brown trout which had migrated into the study site from Lake Michigan. In addition, an extensive sports fishery exists on the AuSable River which could have been responsible for the removal of the faster growing mature trout from the population, resulting in a downward bias to calculated lengths of brown trout in that river.

When the growth curves of 30 brown trout populations in Europe and the United States were compared, two distinct growth patterns were evident. One growth pattern was characterized by an attained total length of 99 mm or more in the first year with relatively linear increases in length in the later years. Brown trout in the AuSable and lower Jordan rivers were representative of this type of growth. The second growth pattern was characterized by an attained length of less than 99 mm in the first year with length increments in later years which resulted in a curvilinear growth curve. The growth of brown trout in the upper Jordan River was of this latter type. The rate of growth of underyearlings was the only factor which consistently differed between populations in the two growth types, and it is possible that the general pattern of growth throughout life is genetically predetermined to be one of the two types shown, and that the expression of one growth pattern over the other depends on the rate of growth of underyearlings.

The response of the sculpin populations to changes in stream eutrophication was similar to that of the brown trout. Slimy sculpin occurred in large numbers in the upper Jordan River but with restricted growth, while in the lower Jordan River this species displayed more rapid growth with an apparent corresponding decrease in density. Mottled sculpin responded in a similar manner to changes in stream eutrophication between the lower Jordan and AuSable rivers.

The condition of yearling brown trout was consistently higher than that of two-year-old trout in each stream. Thomas (1964) suggested that condition factors could be used as an index of growth when populations of the same age at the same season were compared, a high condition being indicative of slow growth. This relationship held for yearling brown trout only, while two-year-old trout in all three river sites exhibited approximately the same condition. The average condition of sculpin was higher for populations in the more eutrophic sites, than it was for populations in the less eutrophic ones.

In all three fish species studied, there was a sharp decline in condition during the spawning season which seemed at least partially due to genetic factors since it occurred in both mature and immature individuals.

It appears that the decline in condition was not entirely related to season since the brown trout and sculpin both exhibited a decline in condition during the spawning season although these species spawned at different times of the year.

In each of the three fish species studied, the instantaneous rate of growth of the fish in the first year was directly related to the level of eutrophication in the stream. That this relationship did not hold for mature brown trout suggests that immature fish are better indicators of stream eutrophication in its early stages than are the mature fish.

Frost (1945), Ball and Jones (1960), and Thomas (1964) have found that the growth of brown trout in later years was directly related to the rate of growth as underyearlings. If this is correct and if the growth of young fish is augmented by increases in stream eutrophication, as was indicated by this study, then the year-to-year changes in the rate of growth of young fish may be a valuable index to changes in stream eutrophication.

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