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RELATIONSHIPS OF SOME ENVIRONMENTAL FACTORS TO GROWTH OF THREE SPECIES OF FISHES IN MICHIGAN

By

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INTRODUCTION

The objectives of this study were twofold: (1) to establish the average monthly length attained for various age groups of the bluegill,[1] Lepomis macrochirus Rafinesque, the yellow perch, Perca flavescens (Mitchill), and the largemouth bass, Micropterus salmoides (Lacépède) in Michigan; (2) to investigate relationships between growth of the three species and lake size, mean depth, surface alkalinity and turbidity. The study was not designed to explore reasons behind the relationships, but rather to determine the existence of such relationships.

Large variations have been reported in growth rates of the same species of fish from different lakes and geographic locations (Carlander, 1953). Considerable differences in growth rates even occur from year to year within a given lake due to environmental changes (Beckman, 1950). Although such variations do occur, average growth rates for a species in a lake or region can be valuable for comparison. Average growth rates for several fishes

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[1] Common and scientific names of fishes in this paper conform to the recommendations in the List of Common and Scientific Names of Fishes from the United States and Canada. Am. Fish. Soc., Spec. Publ. No. 2, 1960.

have been reported by Beckman (1949) for Michigan, for Minnesota by Eddy and Carlander (1942), and for Massachusetts fishes by Stroud (1955), among others.

Relationships between environmental factors and lake productivity have been summarized by Moyle (1949, 1956), Rawson (1942), Northcote and Larkin (1956), and others. Studies on the relationships between environmental factors and growth rates of fishes seem to be less numerous. Growth rates of the lake whitefish, *Coregonus clupeaformis*, lake trout, *Salvelinus namaycush* (Walbaum), northern pike, *Esox lucius* Linnaeus, and walleye, *Stizostedion vitreum vitreum* (Mitchill), did not appear to reflect lake productivity in Northern Saskatchewan (Rawson, 1960). Eddy and Carlander (1940) reported that population density rather than physical and chemical factors of a lake was the most important factor in modifying growth rates.

During routine lake surveys certain physical, chemical and biological measurements are usually obtained. Lakes are mapped and depth contours are drawn in from soundings. Mean depths of the lakes can then be determined from the maps. Alkalinity and turbidity measurements are also usually made. Scale samples and associated fish length measurements are also taken. I used such data as these from the lake survey data in Michigan for this study. The original data and maps are all on file in The Institute for Fisheries Research of The Michigan Department of Conservation.

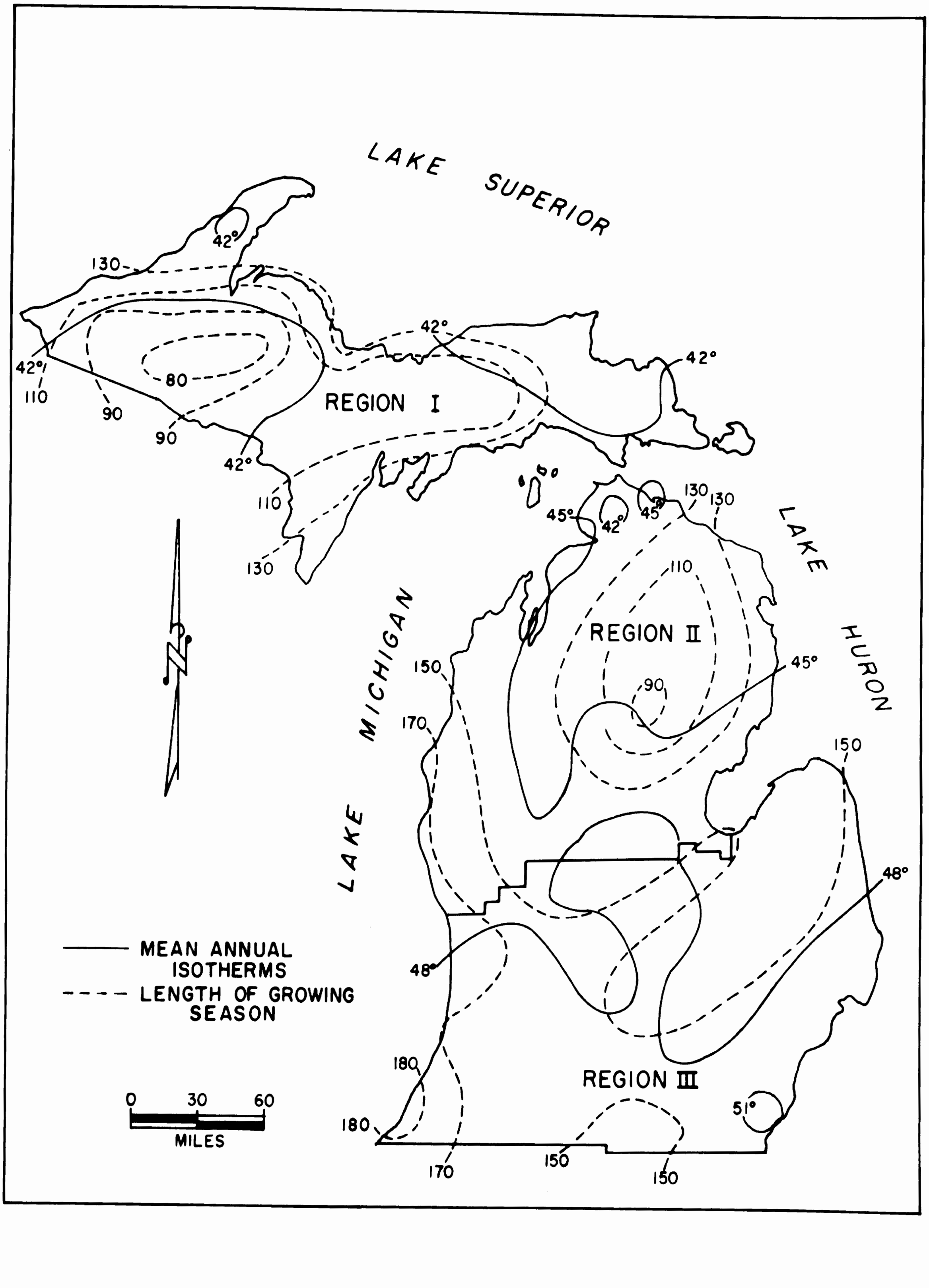
METHODS AND MATERIAL

Basic Data

Environmental and age and growth data from the past thirty years on the lakes studied were obtained from files of the Michigan Institute for Fisheries Research. These data were coded and punched on I. B. M. cards to facilitate analyses. The following information was recorded: county, region, specific lake, selected lake characteristics (surface acreage, mean depth, surface alkalinity, secchi disk reading), selected fish species data (half-month of collection, month of collection, year of collection, method of capture, age group, number of individuals per collection, and average length and average weight for each age group from each collection).

Each lake within a county was assigned a number. Data on individual lakes were grouped by divisions of the state that corresponded to the administrative regions established by the Michigan Department of Conservation (Fig. 1). From an ecological point of view this division is arbitrary, yet the land-use and soils do show major trend-differences, as do the relationships with mean annual isotherms and lengths of the agricultural growing season (number of days from the last killing frost in the spring to the first killing frost in the fall). Region III is characterized by the longest growing

Figure 1.--Map of Michigan. Solid lines indicate mean annual isotherms. Broken lines indicate length of growing season based on number of days from last killing frost in the spring to the first killing frost in the fall.


LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
REGION I
REGION II
REGION III
42°
45°
48°
51°
80
90
110
130
150
170
180
MEAN ANNUAL ISOTHERMS
LENGTH OF GROWING SEASON
0 30 60
MILES
N

season and warmest temperatures. Here the land is used primarily for agriculture, but large industrial cities and urban communities are numerous. Generally, less productive soils and a shorter growing season make Region II less conducive to agriculture than Region I. However, the western edge of Region II does have a substantially longer growing season than its interior because of the modifying effect of Lake Michigan on the temperature. Region I consists of large tracts of forest land and a relatively sparse human population. Swampy areas and agriculturally non-productive soils are also common in this region. Average annual temperatures are lower and growing seasons are generally shorter in Region I than in the other two regions.

The numerical divisions used for surface areas of the lakes, mean depths, surface alkalinities, and secchi disk readings do not conform to any standard classification. Rather narrow divisions were chosen in order to detect any trend that might have been missed with wider divisions. Surface areas of the lakes were stratified as follows: 1-5 acres, 6-14 acres, 15-49 acres, 50-99 acres, 100-299 acres, 300-999 acres, and 1,000 acres and greater. Mean depths of lakes were divided as follows: 1-4 feet, 5-10 feet, 11-15 feet, 16-20 feet, 21-29 feet, and 30 feet and over. Surface alkalinities were divided into the following groups: 0-20 ppm., 21-40 ppm., 41-105 ppm., 106-200 ppm., and 201 ppm. and greater. Secchi disk readings were divided into five groups: 0-3 feet, 4-8 feet, 9-13 feet, 14-19 feet, and 20 feet and greater. Secchi disk readings to the nearest foot were used for the months June through September only in an effort to avoid the effects of early spring and late fall plankton blooms.

Fish collections made between the first and the fifteenth of a month were placed in one group, and those collected between the sixteenth and the end of the month in another. Gear used in collecting was classified as follows: unknown, gill net, trap net, seine, hook and line, poison, shocker, and others. The sex of the fish was placed in one of three groups: undetermined, male, or female.

Growth rates

The ages of the fishes taken between January first and the time of annulus formation in the spring were interpreted as though the annulus was complete at the scale margin. Original records indicated this virtual annulus by an asterisk after the age number. The asterisk signified that the age given was actually one year greater than the number of visible annuli on the scale. All lengths of fishes were based on total lengths at time of capture. When original records showed lengths in millimeters, conversions were made to the nearest tenth of an inch.

Samples were first sorted by region, then by species, and under species by age groups. Age groups were subdivided according to date of collection into half-month divisions as indicated previously. Information on sex of the fishes and type of gear used for sampling was not available for many collections, therefore sexes were combined and type of gear was not considered in establishing growth-rate averages. Any effects of selectivity of gear on size of fishes captured were thus eliminated from consideration. This was unfortunate since some gear undoubtedly selects for fast-growing individuals and other, for slow-growing ones. Examination of the data showed that initial separation of date of collection into half-month groups left many periods with very few collections. Therefore collections were combined finally to include the entire month. Each collection was given equal weight in determining the growth-rate averages for each month and for the age-group averages.

Environmental factors

Two approaches were used in studying the relationships among acreage, mean depth, surface alkalinity, secchi disk reading and fish growth. First the relationships between the individual environmental factors and fish growth were determined. To explore relationships between the combined environmental factors and fish growth the step-wise multiple regression procedure was used. This procedure generates the expression, $Y = b_o + b_1X_1 + b_2X_2 + \ldots + b_kX_k$, variable by variable in order of relative importance

(Ezekiel and Fox, 1959). In this paper the dependent variable Y = total length and the independent variables X_1 = acreage, X_2 = square of X_1, X_3 = mean depth, X_4 = square of X_3, X_5 = surface alkalinity, X_6 = square of X_5, X_7 = secchi disk reading, and X_8 = square of X_7.

Information on environmental factors was not available for many of the fish collections. Consequently much of the age and growth data incorporated in establishing growth rate averages was not used in exploring environmental relationships with fish growth.

Computations were done on the I. B. M. 709 computer at the University of Michigan Computing Center.

RESULTS

Growth of Bluegills

A total of 4,211 collections representing 38,033 fish was used in establishing growth-rate averages for the bluegill. A breakdown by regions showed 227 collections and 1,050 fish from Region I, 1,591 collections and 13,341 fish from Region II, and 2,393 collections and 23,642 fish from Region III.

Growth rates from Regions II and III were similar whereas Region I showed a consistently higher rate of growth for each age group (Table 1). The high average (4.2 inches) obtained for age-group I from Region I may be due to the relatively small number of fish collected. Gear used in collecting may have captured only the very fastest growing one-year-olds; thus selectivity of the gear may have been a factor in causing the high average. Analysis of variance showed a highly significant difference in growth between regions (Table 2). A value of $F_{2,12} = 89.976$ was obtained compared to $F_{.01} = 6.93$ (Snedecor, 1956).

The regions were not equally represented by number of collections. Less than 6 percent of the total number of collections came from Region I. For this reason a monthly average growth rate for the entire state was established by combining the monthly

Table 1.--Average growth rates of bluegills by regions

(Total lengths to nearest 0.1 inch)

	Age-group						
	I	II	III	IV	V	VI	VII
Region I	4.2	4.9	6.1	6.7	7.5	8.1	8.5
Collections	22	37	44	42	37	27	18
Fish	77	193	139	260	153	124	104
Region II	3.4	4.5	5.4	6.3	6.9	7.4	7.8
Collections	116	239	323	342	254	208	109
Fish	1,094	2,244	3,382	3,321	1,953	1,004	343
Region III	3.4	4.4	5.5	6.4	7.0	7.5	7.9
Collections	172	378	536	526	384	259	138
Fish	1,920	3,815	6,639	6,725	2,882	1,218	443

Table 2.--Analysis of variance on growth rates of bluegills from different regions

Source of variance	Sum of squares	d.f.	Mean squares	F
Age groups	47.5123	6	7.9187	883.786
Regions	1.6123	2	.8061	89.976
Residual	.1076	12	.0089	
Total	49.2322	20		

$F_{2,12} = 89.976$ $F_{.01} = 6.93$

average for each region weighted by the number of collections from each region. The average monthly total lengths attained by bluegills is shown in Table 3. Michigan warm-water fishes begin growth in April or later and usually complete the season's growth by October (Beckman, 1943); therefore the months January, February, March and April were combined as were the months October, November and December.

The general growth pattern indicated a relatively steady increase of growth from May through September (Fig. 2). The high average for age-group I in January-April was probably due to insufficient number of collections. Only six collections were represented for that period. For age-groups II and III the higher averages in January-April than in May can be attributed to the selection of the larger fish by the gear used for collecting. Approximately 80 percent of the fish sampled during this period were captured by angling or some unrecorded method. The assumption can be made that many of the unrecorded methods of capture were by hook and line since most of the lakes are frozen over during much of this period. Insufficient data were available for young-of-the-year bluegills to analyze growth during the first year of life.

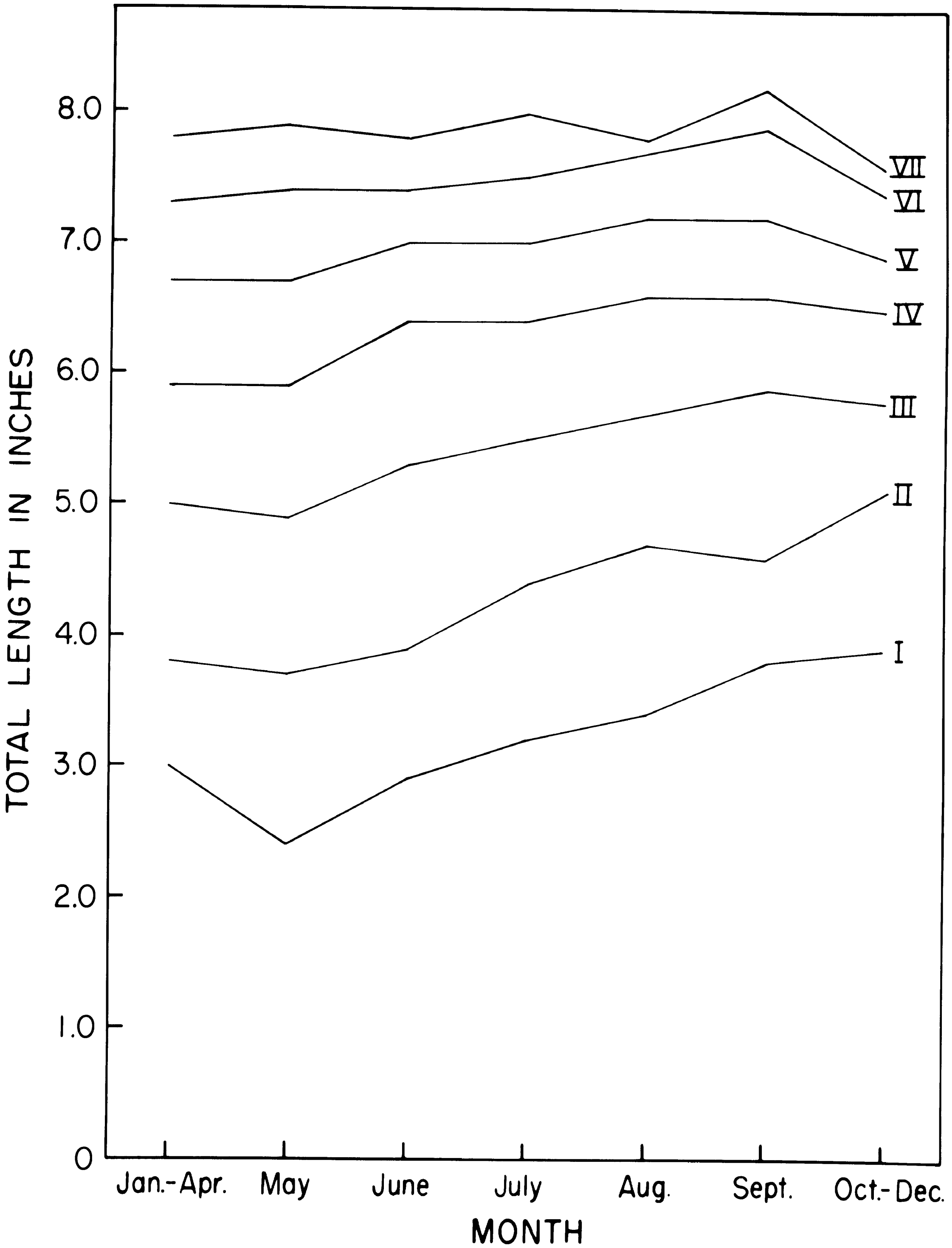
Mean total lengths in inches as attained successively by Michigan bluegills for age-groups I through VII follow: 3.4, 4.4, 5.5, 6.4, 7.0, 7.5, 7.9. Assuming that a bluegill must

Table 3.--State-wide average lengths of bluegills at various months

(Total lengths to nearest 0.1 inch)

	Month							Age-group average
	Jan.-Apr.	May	June	July	Aug.	Sept.	Oct.-Dec.	
Age I	3.0	2.4	2.8	3.2	3.4	3.8	3.9	3.4
Collections	6	15	36	45	68	86	54	310
Fish	252	138	422	419	349	913	598	3,091
Age II	3.8	3.7	3.9	4.4	4.7	4.6	5.1	4.4
Collections	32	58	82	114	151	132	85	654
Fish	344	676	755	945	1,469	1,257	806	6,252
Age III	5.0	4.9	5.3	5.5	5.7	5.9	5.8	5.5
Collections	100	81	127	171	176	156	92	903
Fish	1,044	981	1,834	1,545	1,734	1,950	1,072	10,160
Age IV	5.9	5.9	6.4	6.4	6.6	6.6	6.5	6.4
Collections	124	90	128	168	169	143	88	910
Fish	2,140	1,400	1,640	1,524	1,536	1,229	837	10,306
Age V	6.7	6.7	7.0	7.0	7.2	7.2	6.9	7.0
Collections	109	69	102	123	122	98	52	675
Fish	1,036	840	665	911	578	494	464	4,988
Age VI	7.3	7.4	7.4	7.5	7.7	7.9	7.4	7.5
Collections	91	57	72	88	88	54	44	494
Fish	717	341	297	405	274	187	125	2,346
Age VII	7.8	7.9	7.8	8.0	7.8	8.2	7.6	7.9
Collections	53	29	40	43	43	40	17	265
Fish	219	103	118	173	125	119	33	890

Figure 2.--State-wide seasonal growth pattern of bluegills.


TOTAL LENGTH IN INCHES
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
VII
VI
V
IV
III
II
I
Jan.-Apr.
May
June
July
Aug.
Sept.
Oct.-Dec.
MONTH

be at least six inches long before it is a "keeper" from an angler's viewpoint, the average Michigan bluegill must enter its fifth year of life (age-group IV) before it is of value to a fisherman.

Growth of Yellow Perch

Growth rate averages for the yellow perch were compiled from 988 collections and 5,191 fish from Region I, 2,397 collections and 13,806 fish from Region II, and 1,479 collections and 7,098 fish from Region III. Combining the regions gave a total of 4,864 collections and 26,095 fish used in establishing state-wide growth averages.

A difference in growth rates for yellow perch in the three regions was evident (Table 4). Yellow perch from Region III were consistently slower growing than from Regions I and II. Analysis of variance showed the difference in growth to be highly significant. A value of $F_{2, 14} = 22.638$ was obtained (Table 5).

The same method for compiling the monthly growth average was used for yellow perch as for bluegills. The average length attained by various age groups at different months is shown in Table 6. Mean total lengths in inches as attained successively by yellow perch for age-groups 0 through VII are: 3.1, 4.6, 6.1, 7.0, 8.0, 9.0, 9.9, 10.7. Seasonal growth trends are shown in Figure 3.

Table 4.--Average growth rates of yellow perch by regions

(Total lengths to nearest 0.1 inch)

	Age-group							
	0	I	II	III	IV	V	VI	VII
Region I	3.1	4.8	6.3	7.3	8.3	9.4	10.1	10.7
Collections	9	47	138	194	220	172	130	78
Fish	42	417	971	1,509	1,183	600	319	150
Region II	3.3	4.6	6.0	6.9	8.0	8.9	10.0	10.9
Collections	20	178	439	527	466	376	240	151
Fish	148	1,340	3,145	3,506	2,975	1,541	744	407
Region III	2.3	4.3	5.9	6.7	7.5	8.7	9.7	10.3
Collections	19	156	331	366	277	171	97	62
Fish	99	1,104	2,083	1,859	1,062	545	237	109

Table 5.--Analysis of variance on growth rates of yellow perch from different regions

Source of variance	Sum of squares	d.f.	Mean squares	F
Age groups	149.34	7	21.3342	694.925
Regions	1.39	2	.6950	22.638
Residual	.43	14	.0307	
Total	151.16	23		

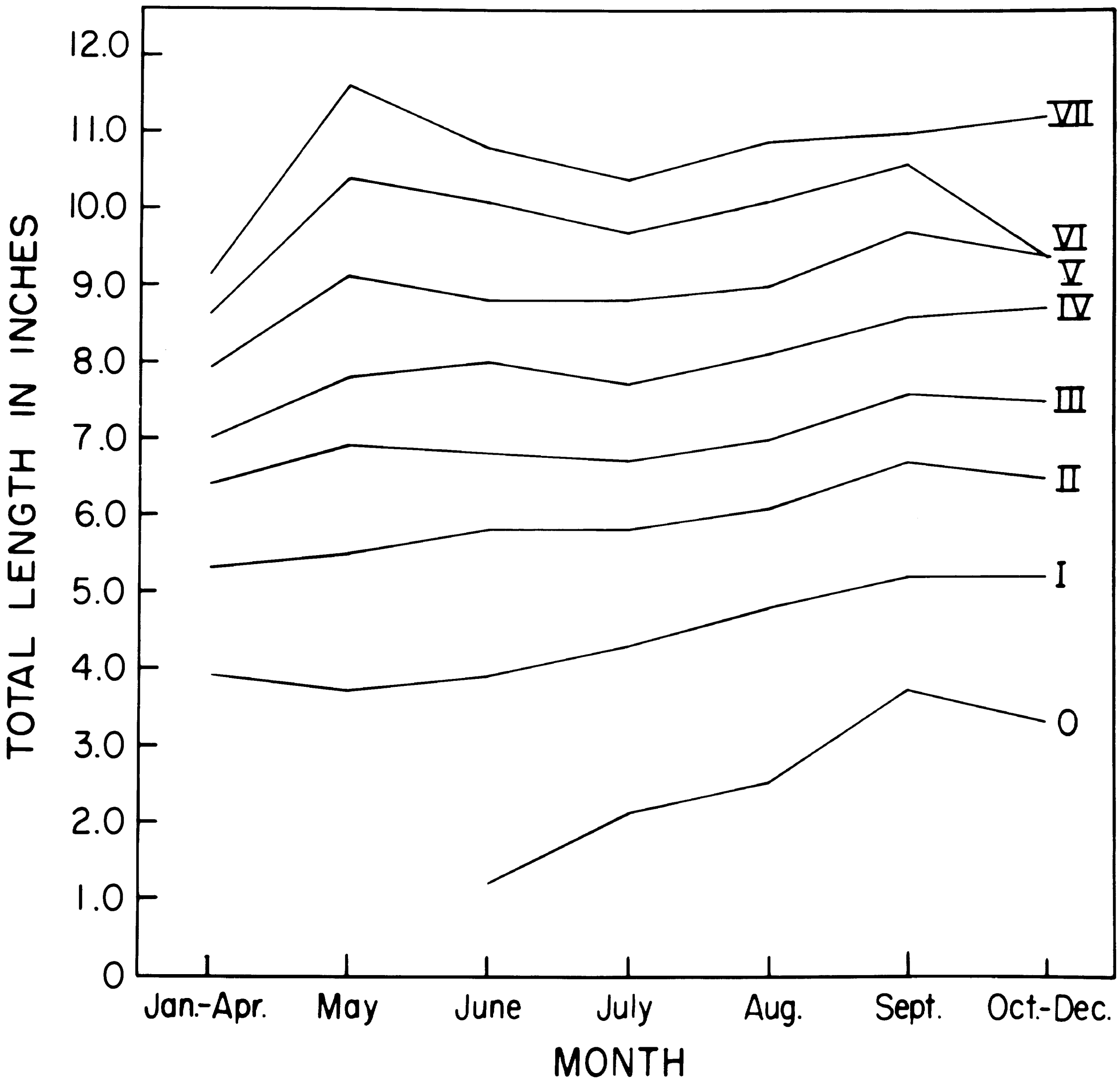
$F_{2,14} = 22.638$ $F_{.01} = 6.51$

Table 6.--State-wide average lengths of yellow perch at various months

(Total lengths to nearest 0.1 inch)

	Month							Age-group average
	Jan.-Apr.	May	June	July	Aug.	Sept.	Oct.-Dec.	
Age 0	...	...	1.2	2.1	2.5	3.7	3.3	3.1
Collections	...	...	1	6	15	21	5	48
Fish	...	...	1	20	58	181	29	289
Age I	3.9	3.7	3.9	4.3	4.8	5.2	5.2	4.6
Collections	7	14	56	83	95	88	38	381
Fish	37	230	331	549	642	767	305	2,861
Age II	5.3	5.5	5.8	5.8	6.1	6.7	6.5	6.1
Collections	61	46	126	200	231	169	75	908
Fish	439	354	859	1,327	1,544	1,177	499	6,199
Age III	6.4	6.9	6.8	6.7	7.0	7.6	7.5	7.0
Collections	92	73	141	262	279	161	79	1,087
Fish	542	353	798	2,054	1,581	1,090	456	6,874
Age IV	7.0	7.8	8.0	7.7	8.1	8.6	8.7	8.0
Collections	89	60	121	228	251	141	73	963
Fish	395	264	629	1,649	1,314	628	334	5,213
Age V	7.9	9.1	8.8	8.8	9.0	9.7	9.4	9.0
Collections	57	41	97	193	181	105	45	719
Fish	176	189	296	794	712	342	177	2,686
Age VI	8.6	10.4	10.1	9.7	10.1	10.6	9.4	9.9
Collections	37	17	64	130	128	63	28	467
Fish	107	48	162	371	393	147	72	1,300
Age VII	9.1	11.6	10.8	10.4	10.9	11.0	11.2	10.7
Collections	17	20	44	84	76	37	13	291
Fish	34	37	92	198	200	75	30	666

Figure 3.--State-wide seasonal growth pattern of yellow perch.



TOTAL LENGTH IN INCHES
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
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VII
VI
V
IV
III
II
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Jan.-Apr.
May
June
July
Aug.
Sept.
Oct.-Dec.
MONTH

Both young-of-the-year and age-group I showed a steady increase of growth from June and May respectively through September. Most rapid growth occurred for age-group II and older fish during two periods: spring and early summer and during August and September. This growth pattern is evident from the monthly growth increments for each age group. Two-year-old and older fish had a negative or zero growth increment in July. The warmest month of the year is July.[2] Therefore high temperatures either directly or indirectly may retard growth during that period. Another possibility is that angling mortality is highest among the fastest growing individuals of each age group. This seems especially feasible since "negative growth" in July does not appear until the fish are nearly seven inches in length. Probably a combination of the two factors contributes to the growth pattern shown by the yellow perch. In contrast to the foregoing bimodal growth pattern, the yellow perch of Lake Erie had a single growth spurt during July (Jobes, 1952).

Monthly increments of growth for each age group were obtained by determining differences between the average lengths of successive months. Overall in Michigan, age-group III and older fish showed the two largest growth increments in May and September except for seven-year-old fish. The two largest increments for age-group VII were in May and August.

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[2] Climatological Data. U. S. Dept. of Commerce, Annual Summary, Vol. 76, No. 13, 1961.

Growth of Largemouth Bass

Growth averages for the largemouth bass were compiled from 2,408 collections representing 9,416 fish. Of this total, 144 collections and 412 fish were from Region I, 1,096 collections and 4,244 fish from Region II and 1,168 collections and 4,760 fish from Region III. Approximately 48.5 percent of the total number of collections were from Region III, 45.5 percent from Region II and 6 percent from Region I.

A significant difference in growth rates among the three regions was not apparent (Table 7). Although young-of-the-year from Region I averaged six-tenths of an inch shorter than young-of-the-year from Region III, the average for the succeeding age group from Region I was five-tenths of an inch longer than for Region III. The relatively small number of collections from Region I makes the result of any comparison uncertain. Analysis of variance showed the difference in growth among the regions was not significant at the 1 percent level (Table 8). A value of $F_{2, 14}$ = 2.698 was obtained. This conclusion is based on the assumption that little, if any, interaction between age groups and regions exists. Replication of data would be necessary to test the validity of the assumption.

Average state-wide monthly growth averages are shown in Table 9. The largemouth bass mean total lengths in inches in

Table 7.--Average growth rates of largemouth bass by regions

(Total lengths to nearest 0.1 inch)

	Age-group							
	0	I	II	III	IV	V	VI	VII
Region I	2.8	6.5	9.8	11.3	12.9	13.8	15.3	16.6
Collections	8	18	26	27	26	18	11	10
Fish	69	95	89	41	52	30	16	20
Region II	3.7	6.2	8.6	10.7	12.2	13.7	15.2	16.9
Collections	43	153	241	245	179	125	67	43
Fish	331	743	1,315	877	564	248	110	56
Region III	3.6	6.0	8.4	10.4	12.1	13.4	15.1	16.5
Collections	58	187	261	256	171	111	72	52
Fish	296	1,036	1,195	967	608	382	173	103

Table 8.--Analysis of variance on growth rates of largemouth bass from different regions

Source of variance	Sum of squares	d.f.	Mean squares	F
Age groups	431.6162	7	61.6594	434.527
Regions	.7658	2	.3829	2.698
Residual	1.9875	14	.1419	
Total	434.3695	23		

$F_{2, 14} = 2.698$ $F_{.01} = 6.51$

Table 9.--State-wide average lengths of largemouth bass at various months

(Total lengths to nearest 0.1 inch)

	Month							Age-group average
	Jan.-Apr.	May	June	July	Aug.	Sept.	Oct-Dec.	
Age 0	...	...	1.1	2.6	2.9	4.0	4.0	3.6
Collections	...	...	1	6	33	47	22	109
Fish	...	...	2	23	186	352	133	696
Age I	4.4	4.1	4.5	5.4	6.4	6.9	7.1	6.1
Collections	10	17	38	60	97	90	46	358
Fish	24	74	157	227	466	604	322	1,874
Age II	6.9	7.2	7.6	8.7	9.1	9.3	9.4	8.6
Collections	25	49	76	116	120	90	52	528
Fish	115	348	508	419	460	488	261	2,5[illegible]
Age III	9.4	9.8	10.1	10.6	11.0	11.1	10.9	10.6
Collections	36	51	80	125	106	86	44	528
Fish	130	262	307	373	332	327	154	1,885
Age IV	11.7	11.6	11.8	12.3	12.6	12.4	12.7	12.2
Collections	31	37	73	90	66	50	29	376
Fish	184	250	213	221	148	137	71	1,224
Age V	13.3	13.4	13.6	13.4	13.9	13.4	14.7	13.6
Collections	23	29	50	61	43	32	16	254
Fish	1[illegible]1	134	109	109	63	41	43	660
Age VI	14.9	14.6	14.8	15.0	15.2	15.9	16.7	15.1
Collections	22	21	29	27	27	14	10	150
Fish	76	57	50	40	38	22	16	299
Age VII	16.2	16.9	15.9	17.2	16.9	17.1	17.1	16.7
Collections	18	10	21	15	22	12	7	105
Fish	55	26	28	17	25	21	7	179

successive years of life beginning with age-group 0 are as follows: 3.6, 6.1, 8.6, 10.6, 12.2, 13.6, 15.1, 16.7.

Seasonal growth trends are shown in Figure 4. A general increase in growth for age-groups 0 through IV from May through September is apparent. The small number of collections during some months probably obscures the true growth pattern for older largemouth bass.

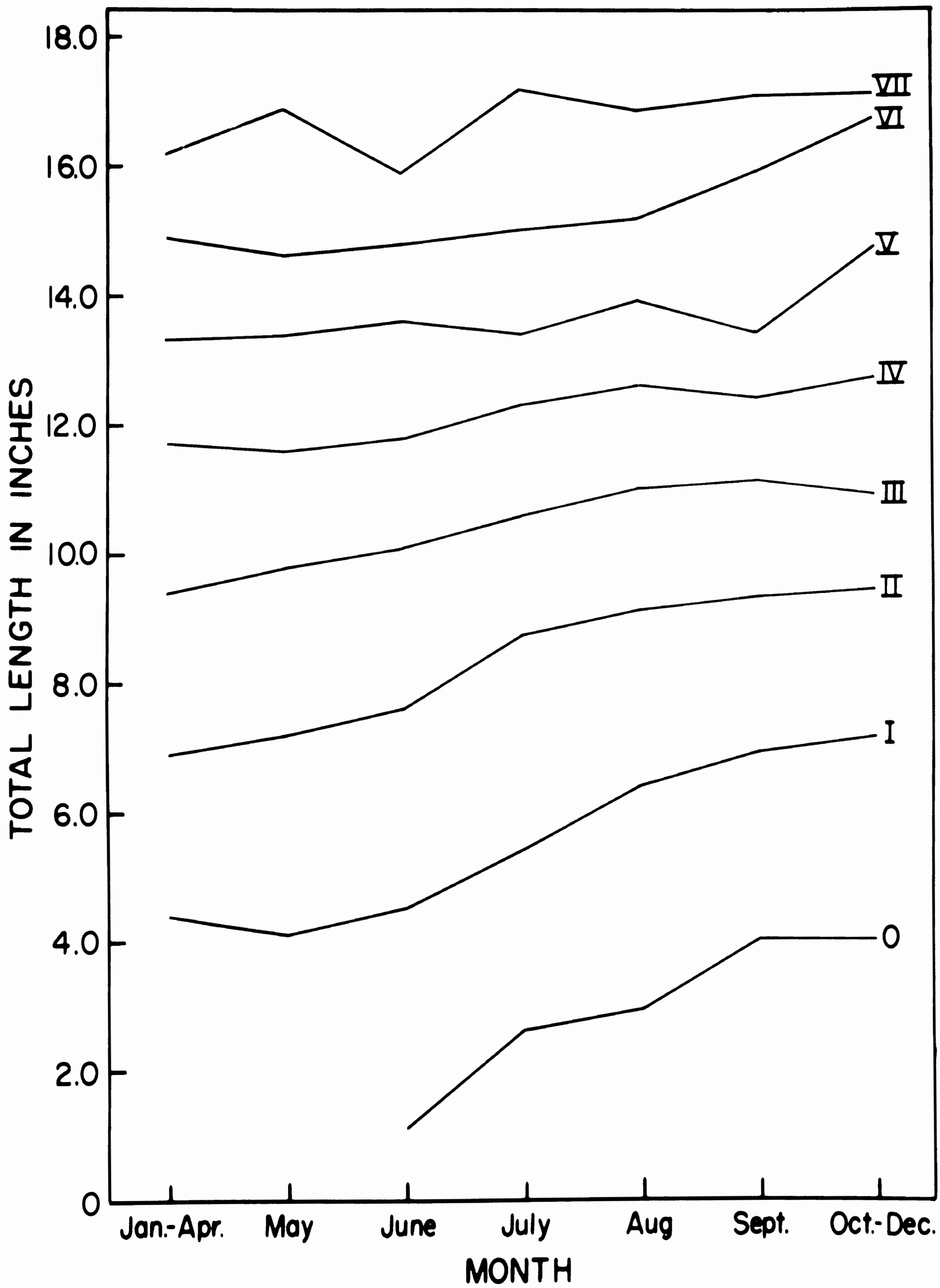
Relationships of Environmental Factors to Fish Growth

Lake size

Correlation coefficients of the independent variables and growth of the various age groups were determined (Table 10). There appears to be little relationship between lake size and growth rates of the bluegill, yellow perch and largemouth bass. The highest significant correlation was $r = .2384$ for age-group IV bluegills. Significant correlations were also obtained for age-groups III and VI bluegills. Only age-group I yellow perch showed a significant correlation; an inverse relationship was obtained with $r = -.1549$.

Growth of largemouth bass in Oklahoma was generally fastest in the largest bodies of water (Jenkins and Hall, 1953). This does not hold for the species in Michigan; here the only significant correlation was $r = .1822$ for age-group II.

Figure 4.--State-wide seasonal growth pattern of largemouth bass.



TOTAL LENGTH IN INCHES
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
VII
VI
V
IV
III
II
I
0
Jan.-Apr.
May
June
July
Aug
Sept.
Oct.-Dec.
MONTH

Table 10.--Correlation coefficients of fish growth and the independent variables

X_1 = Surface area X_5 = Surface alkalinity Y = Length of fish
X_3 = Mean depth X_7 = Turbidity N = No. of collections

* = Significant at 5 percent level
** = Significant at 1 percent level

Species	Age-group	N	X_1 vs Y	X_3 vs Y	X_5 vs Y	X_7 vs Y
Bluegill	I	137	-.1340	-.1343	-.1072	.0989
	II	332	.0065	-.0358	-.1382	-.0304
	III	450	.2012**	.0728	.1977**	-.1264**
	IV	448	.2384**	.1671**	.2189**	-.1429**
	V	349	.0895	.2590**	.2514**	-.0721
	VI	250	.1484*	.3669**	.2414**	-.0484
	VII	139	.0604	.4147**	-.1114	.2022*
Yellow perch	I	225	-.1549*	-.0937	-.0541	.0915
	IV	602	-.0408	-.1003*	-.0115	-.1253**
	V	450	.0260	-.0862	.0073	-.0473
	VI	317	.0752	-.0292	-.0984	.0123
	VII	195	.0963	-.0414	-.1137	.0329
Largemouth bass	I	182	.0896	-.1160	-.0187	.1007
	II	291	.1822**	-.0048	.0676	-.1229*
	III	283	.0665	-.0221	-.0367	-.0552
	IV	198	.1282	.0596	-.0186	-.1404*
	V	133	.1368	.1665	-.0858	-.0459
	VI	91	.0912	.2200*	-.2820**	.1008
	VII	53	-.0602	.1310	-.1888	.2157

Mean depth

Very little relationship was found between mean depth and growth rates of yellow perch and largemouth bass. The only significant correlations were r = -.1003 for age-group IV yellow perch and r = .22 for age-group VI largemouth bass. However, highly significant correlation coefficient values were obtained for age-groups IV through VII bluegills. From age-group III on, successively older fish showed stronger relationships. Even though the correlation coefficients were significant at the one percent level, the low values (r = .1671 to .4147) do not indicate a strong relationship between mean depth and growth rates of the species studied.

Alkalinity

No significant relationship was found between surface alkalinity and growth of the yellow perch. A highly significant relationship was obtained for age-group VI largemouth bass. Kramer and Smith (1960) reported no relationship between total alkalinity and first-year growth of largemouth bass.

A significant negative correlation was found between alkalinity and age-group II bluegills. Significant positive correlations were found for age-groups III through VI. These data do not indicate strong relationships since the highest value obtained was r = .2514 for age-group V.

Turbidity

Natural waters are all turbid to some degree (Welch, 1952). The amount of turbidity found in natural waters generally is not lethal to fish (Wallen, 1951). Although indirectly the effects of turbidity on fish populations may be significant, no strong relationships could be shown between turbidity and fish growth. The largest correlation coefficients obtained were $r = .2022$ for age-group VII bluegills, $r = -.1253$ for age-group IV yellow perch and $r = .2157$ for age-group VII largemouth bass.

Combined environmental factors

Since singly the environmental factors were not closely related to fish growth it was of interest to investigate the combined effects of the independent variables and fish growth. The stepwise multiple regression procedure as explained earlier was used. A summarization of the results are shown in Table 11. The average Y (fish length) is given for each age group. The smallest set of independent variables which significantly (1 percent level) contributed to the prediction of Y are also given. A measure of the closeness of fit of the regression is designated by the multiple correlation coefficient (R). The percent of the total variation in Y that is explained by the predicting equation is shown by the coefficient of determination (R^2).

Table 11.--Relationships of combined environmental factors to fish growth

Y = Average length in inches per age group
Variables = Contributed significantly (1 percent level) to prediction of Y
R = Multiple correlation coefficient
R^2 = Coefficient of determination in percent
N = Number of collections
* = Significant at 5 percent level
** = Significant at 1 percent level

Species	Age-group	Y	Variables	R	R^2	N
Bluegill	I	3.26	X_8,X_7,X_4,X_2,X_1	.355**	12.6	137
	II	4.33	X_5,X_6,X_1,X_7,X_8	.268**	7.2	332
	III	5.26	$X_6,X_2,X_5,X_1,X_4,X_8,X_7$	.364**	13.2	450
	IV	5.89	$X_2,X_6,X_5,X_1,X_4,X_7,X_8$	.486**	23.6	448
	V	6.49	$X_9,X_5,X_4,X_2,X_3,X_8,X_7$	.493**	24.3	349
	VI	7.16	X_4,X_6,X_2,X_5,X_8,X_7	.567**	32.2	250
	VII	7.91	X_4,X_6,X_2,X_1	.506**	25.6	139
Yellow perch	I	4.35	$X_2,X_8,X_7,X_1,X_3,X_4X_6,X_5$	.287**	8.2	225
	IV	7.72	X_7,X_2,X_1,X_5	.238**	5.6	602
	V	8.82	X_4,X_1,X_2,X_6	.237**	5.6	450
	VI	9.81	X_6,X_1,X_2,X_7,X_4,X_3	.257**	6.6	317
	VII	10.64	X_6,X_1	.176*	3.1	195
Large-mouth bass	I	5.90	X_8,X_3,X_2,X_1,X_4	.291**	8.4	182
	II	8.26	$X_2,X_1,X_8,X_7,X_3,X_4,X_6,X_5$	.385**	14.8	291
	III	10.26	X_2,X_1,X_3,X_4,X_5,X_6	.270**	7.3	283
	IV	11.65	$X_2,X_1,X_7,X_4,X_3,X_5,X_6$	.457**	20.8	198
	V	13.14	X_2,X_1	.248**	6.1	133
	VI	14.77	X_5,X_3	.376**	14.1	91
	VII	16.36	---			53

Highly significant (1 percent level) R values were obtained for all age groups except two. Age-group VII yellow perch was significant at the 5 percent level. None of the independent variables provided significant information toward a predicting equation for age-group VII largemouth bass.

Even though the multiple correlation coefficients were significant for most age groups, the regressions of the variables used on growth accounted for a relatively small amount of variation in growth. The predicting equation with the highest R^2 value (bluegills, age-group VI) accounted for 32.2 percent of the variation in growth. The data show that the independent variables considered cannot be used either singly or in combination as useful predictors of fish growth.

DISCUSSION

Although a large amount of age and growth data were used, the results may not give a true indication of growth for the species studied because of inadequate sampling. An average of 2.5 to 10 fish per collection for an age group would indicate that many populations were not adequately sampled. This is substantiated by the large variation in monthly growth rates especially among the older age groups. Generally the older age groups contained fewer fish per collection.

The longest growing season might be expected to result in the most rapid growth rates. This was not so for the species studied. However, the shortest growing season (Region I) showed the fastest growth rate for bluegills. Mortality of young may be highest in Region I, because this region lies in the northern part of the bluegill range. Highest early mortality might result in the lowest population density and, hence, in the fastest growth rates. Depressed intraspecific competition may thus be a factor that masks the effect of shortness of growing season. The longest growing season (Region III) showed the slowest growth rate for yellow perch. Furthermore, the highest temperatures characteristic of Region III may result in a longer period of cessation of growth. Therefore the actual growing period for yellow perch may not be longer in this region than in the other two regions. Grice (1959) reported that the rate of growth of yellow perch and largemouth bass was more dependent on population density than on length of growing season or other factors affecting growth.

Comparisons with the summaries given by Carlander (1953) showed Michigan fishes to be growing at an "average" rate. Growth of yellow perch in Michigan compared favorably with the median values given by Carlander (1953). Growth of the bluegill and the largemouth bass was similar to the third quartile values given by Carlander (1953). However, true growth rates for Michigan fishes may be higher than were found in this study, especially for the bluegill and yellow perch. Many of the samples were from lakes in which stunted populations of bluegills and yellow perch were a problem. Consequently, the lakes from which samples were taken were probably biased toward the slowest growing populations of bluegills and yellow perch.

The phenomenon of growth that the slower growing individuals of a population live longer than the faster growing fish may be another factor that has biased the growth rate averages given in this report. Possibly the slowest growing fish are the ones that are represented in the samples, especially among the oldest age groups. Systematically, periodic and intensive sampling of a population would be necessary to investigate this characteristic of growth. The nature of this study did not permit investigation of this phenomenon.

Strong relationships between lake size, mean depth, surface alkalinity, turbidity and fish growth did not exist. The correlations between the combined environmental factors and fish growth may have been changed considerably if other factors affecting growth had been considered. Although the environmental factors usually measured during routine lake surveys, and used in this study, may serve other purposes, they do not appear to be useful indicators of growth rates of bluegills, yellow perch and largemouth bass.

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