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Fish Communities in Warmwater Lakes

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FISH COMMUNITIES IN WARMWATER LAKES [1]

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Abstract

Fish populations and communities in 229 typical lakes in the Lower Peninsula were sampled with large seines from 1957 to 1964. The number of species captured varied from 4 to 19 per lake. Warmwater species comprised most of the fish biomass in 207 lakes; coolwater species predominated in 22 lakes. Bluegills made up more than half of the fish biomass in 41% of the lakes. In 4 to 7% of the lakes either largemouth bass, carp, or white sucker comprised the bulk of the fish community. Bluegill plus largemouth bass was the most important combination of species.

The average fish community in Region II lakes consisted of 36% bluegill, 18% largemouth bass, 11% white sucker, 9% yellow perch, 6% northern pike, 5% pumpkinseed, and 3% carp, plus lesser amounts of other species. The composition of the average lake in Region III was the same, ±2%, except that bluegills were 41% and the percentages for carp and white sucker were reversed. Strongly piscivorous species comprised 29% of the fish biomass in Region II and 22% of the fish biomass in Region III.

The communities could not be readily sorted into natural subtypes on the basis of species composition, except that warmouth, lake chubsucker, and grass pickerel were warmwater species restricted to southern Michigan. Some of the expected relationships among environmental factors and species abundance were confirmed by factor analysis, but most of the variation in fish distribution was not explained. Cluster analysis was useful for identifying which communities were the most similar.

On the species population level, there was evidence that the proportion of large-sized fish depended on growth which, in turn, depended on density.

In general, better sport fishing was experienced in deeper, clearer, moderately vegetated lakes which had a layer of cool, oxygenated water in summer. Indices favorable to good fishing were relatively high proportions of

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[1] Contribution from Dingell-Johnson Project F-35-R, Michigan.

piscivors (especially largemouth bass) and low proportions of bluegill, carp, and white sucker, fast growth of bluegills, and high percentages of large-sized bluegill and pumpkinseed. The quality of fishing was predictable, in part, from criteria based on these characteristics.

Introduction

The inland lakes of Michigan are diverse and their fish fauna varied. While each lake community is somewhat unique, it is important to recognize similarities and differences useful to fisheries management. In an earlier paper I broadly related fish abundance and distribution to certain limnological and climatic characteristics of lakes (Schneider 1975). This paper will describe in greater detail the structure of sport fish communities in lower peninsula lakes.

Methods

Data on the fish communities and environmental characteristics of 229 inland lakes in the lower peninsula were selected from the files of the Fisheries Division, Michigan Department of Natural Resources. These lakes were selected because they had been sampled with large seines (a relatively unbiased gear) and contained relatively diverse and stable fish populations. I excluded lakes which had been significantly altered by fisheries management or winterkills of fish. Thus, the selected study lakes were the best available samples of relatively unperturbed fish communities.

Most (65%) of the lakes were south of an imaginary line connecting Bay City and Muskegon (Region III), the rest were between this line and the Straits of Mackinaw (Region II). This line falls approximately on the 1800° isotherm for growing degree days above a base of 55 F (Van Den Brink et al. 1971).

Warmwater species of fish predominated in most lakes; coolwater species in some. Stocked trout made up a minor part of the catch in 10 of the lakes. The fishing quality of 184 of the lakes was ranked as either poor, average, or good, based on opinions of the lake's users which had been recorded by the seining crews. Reputed fishing problems such as stunted panfish, excessive populations of carp, etc., were also noted by the crews.

The seines were operated in spring and fall, 1957 to 1964. If a lake was sampled more than once, only the most representative (usually the largest) sample was selected. Field crews recorded for each species the number caught and an abbreviated length-frequency distribution. Their records of field weights were available for a few of the lakes, but for most of the lakes weights had to be estimated from the numbers of fish caught, their length-frequency, and state average length-weight relationships. The weight figures were then used to calculate the percentage each species contributed to the total catch (community). Also computed were the numbers and pounds caught per acre seined.

Scale samples were often taken to determine growth of bluegills, pumpkinseeds, yellow perch, largemouth and smallmouth bass, northern pike, and walleyes. Most of the age determinations were made by P. W. Laarman. Average growth for a species was computed as the deviation from the Michigan average by the method of Laarman, Schneider, and Gowing (1981).

Several different seines were used to sample the fish communities. They varied from 800 to 1,600 feet long and from 15 to 30 feet deep. The smallest mesh in the bags varied from 0.7 to 2.0 inches (stretch). They were made of either cotton or nylon. Catches from all types of seines were pooled for the analysis because the differences in their efficiencies were small compared to other sources of variability. The nets with smaller mesh naturally captured more fish less than 3.5 inches long than the nets with larger mesh, but these small fish contributed little to the total catch on a weight basis.

Although a large seine is a relatively unbiased sampling tool compared to other types of gear, it does not always give an accurate picture of the fish community. The seine is restricted to snag-free, inshore habitats adjacent to a firm beach--and samples only the fishes found there. Small minnows and bottom species (such as bullheads) are usually somewhat undersampled, and catches of all species (and sizes) are erratic due to schooling and to migrations inshore, offshore, and along shore. Standing crops per unit area seined are usually underestimated because some of the encircled fish escape when vegetation, drop-offs, or snags are encountered. However, for all but a few of the 229 lakes examined, the seine samples seem to have given a satisfactory picture of the community composition on a weight basis and of the size-frequency of panfish. The standing crop data did not seem to be very reliable on a lake-by-lake basis, and the overall averages in Table 1 of 42-45 pounds per acre are much lower than the 88-182 pounds per acre averages obtained by other methods for similar types of lakes (Schneider 1973 and 1978).

Environmental characteristics of lakes used in the analyses were lake area, alkalinity, secchi disk transparency, and maximum and mean depth. Also used were a climate index (number of growing degree days above a base of 55 F), an index of macrophyte abundance (ranked 1 through 5 for sparse through abundant), and an index of oxygen-thermal type (typed 1 through 5 for lakes with at least 2 ppm of dissolved oxygen in the bottom waters of the hypolimnion during midsummer through unstratified lakes). The climate, macrophyte and oxygen-thermal indices were more fully described by Schneider (1975).

The data were computerized and subjected to various types of analyses to help define groupings and interrelationships. Multivariate techniques used included principal components, factor, canonical, regression, and cluster analyses.

The common names of fishes used in this report are defined in Table 1 and follow the American Fisheries Society Special Publication No. 12, "A list of common and scientific names of fishes from the United States and Canada" (4th edition, 1980).

Results and discussion

Diversity.--The number of species captured varied from 4 to 19 per lake. Relatively rare species often were not captured. Generally, large lakes in the southern part of the state which were connected to large rivers had the greatest diversity, and small, northern, seepage lakes had the least diversity. This is attributed to the size and diversity of habitats, climatic limitations on the distribution of certain species, and accessibility of the lake to colonization by fish.

Distribution.--The north-south gradient of temperature up the lower peninsula influenced all species to some degree, but noticeably limited the distribution of some common warmwater species (Table 1). Virtually restricted to the area of more than 1,800 growing degree days (Region III) were lake chubsucker, grass pickerel, and warmouth. Noticeably more frequent in Region III than Region II were carp, bowfin, green sunfish, golden shiner, and longnose gar. Of these species, only the carp occasionally achieved a dominant role.

Composition.--All of the study lakes contained mixtures of so-called warmwater and coolwater species. Included in the warmwater group, in addition to the species just mentioned above, are bluegill, pumpkinseed, largemouth bass, black crappie, and bullheads (not distinguished in the seine reports as to yellow, brown, or black). Species in the coolwater group are yellow perch, rock bass, smallmouth bass, northern pike, walleye, and white sucker.

The warmwater species comprised the bulk of the fish biomass in 207 lakes and the coolwater species predominated in 22 lakes (19 of which were in Region II).

The ratio (expressed as a percentage) of strongly piscivorous species --largemouth and smallmouth bass, northern pike, walleye, grass pickerel, gar, and bowfin--to the total fish community on a weight basis (P/t) varied from 1 to 95%. The average was 25%, and two-thirds of the communities were between 10 and 40%.

Surprisingly, the species composition of lakes in Region II were on the average similar to lakes in Region III (Table 1). The average fish community in Region II lakes consisted of 36% bluegill, 18% largemouth bass, 11% white sucker, 9% yellow perch, and 6% northern pike, plus lesser amounts of minor species. The composition of the average lake in Region III was the same, ±2%, except that bluegill was 5% higher and the percentages for carp and white sucker were reversed. The P/t index was 29% for Region II lakes and 22% for Region III lakes.

The bluegill was the predominant species. It comprised more than half of the fish biomass in 41% of the lakes, and it was more abundant than any other species in 63% of the lakes. The corresponding figures for carp were 7% and 11%; for largemouth bass, 6% and 14%; for white sucker, 4% and 6%; for yellow perch 1% and 3%; and for walleye 0.4% and 0.4%.

No other species made up more than half of the standing crop of any lake, but occasionally either northern pike (2%), black crappie(2%), pumpkinseed (1%), or smallmouth bass (0.4%) was more abundant than any other species in a community. Bluegill, carp, largemouth bass, or white sucker were extremely dominant (as much as 90% of the sample) in some lakes (Table 1).

Bluegill plus largemouth bass was the most important combination in the warmwater fish communities without carp. Bluegill and largemouth bass ranked #1 and #2 (or #2 and #1, respectively) and also combined for more than 50% of the community biomass in 95 lakes. In the other warmwater communities yellow perch, pumpkinseed, black crappie, or northern pike slipped into prominence as #2 or #3, or rarely, as #1. In the coolwater communities in which suckers were less than 20% of the biomass, yellow perch were combined with either largemouth bass (2 lakes), smallmouth bass(1 lake), northern pike (2 lakes), or walleyes (1 lake).

Aside from these generalities, the communities could not be classified into more distinct natural subtypes because the species mixed in continually varying ratios--within the ranges indicated in Table 1. This suggests either that community composition was fine-tuned to subtle differences in the environments, or simply that the subtypes were obscured by sampling variability.

However, an artificial classification of the 229 communities into seven subtypes was devised (Table 2). First, the lakes in which largemouth bass, carp, or white sucker comprise 50% or more of the biomass were sorted out, then the remaining lakes were grouped according to four levels of bluegill abundance. Typical (and usually desirable) warmwater fish communities fell under the headings "bluegill, 25-49%" and "bluegill, 50-74%." The composition of these communities was predominately bluegill (37-61%), followed by largemouth bass (about 15%), then by pumpkinseed, yellow perch, and black crappie (each about 6%). Lakes with 0-25% bluegill contained either a preponderance of coolwater sport fish or near equal mixtures of species. Lakes with 75-90% bluegills, or more than 50% of either largemouth bass, carp, or white sucker, generally had undesirable, "unbalanced" communities, that did not provide satisfactory sportfishing (see subsequent section on fishing quality). From the perspective of fisheries management, the important components of a fish community of a lake seem to be those species comprising more than 5% of the biomass.

Associations.--The statistical technique of factor analysis was used to explore for relationships among the distribution and abundance of fish species and certain environmental characteristics. Smith and Fisher (1970) successfully used this technique to help describe the distribution patterns of Kansas fishes. The technique generates a series of factors, each one of which may be thought of as a combination of variables which are correlated with each other (either positively or negatively), and also scaled factor loadings, which are akin to partial correlation coefficients in that they express how strongly (on a scale of -1.0 to +1.0) each variable relates to each factor.

The environmental characteristics included in the factor analysis were lake area, maximum depth, climate (expressed as growing degree days), macrophyte density, and Secchi disk transparency (a measure of water clarity and/or productivity). A complete set of these data were available for 126 lakes. Shown in Table 3 are the results obtained from a factor analysis of the correlation matrix in which species abundance was measured in pounds caught per acre seined. Similar results were obtained using numbers of fish caught per acre seined.

The first four factors derived by the technique were the best statistically, yet explained just 37% of the total variance in the data set (Table 3). Additional factors were computed but they accounted for little of the variance and were more difficult to interpret biologically. Apparently, most of the variance in the data set was due to sampling error, to the effects of unmeasured environmental characteristics, and to those other sources of variation common to biological systems. Because the factors were not statistically powerful, they were not useful for sorting lakes into clear-cut groups.

Factor 1 indicated that the abundance of most warmwater species--especially the subgroup of lake chubsucker, grass pickerel, minnows (mostly golden shiner), bullheads, and warmouth--related positively (i.e., have the highest positive scaled factor loadings) to warmer climate and denser macrophytes, and somewhat negatively to lake depth. Area and transparency had factor loadings close to 0.0 and were unimportant. Factor 2 indicated that walleye and bowfin were strongly associated with large lakes, and somewhat associated with cooler climate and low clarity. This result seems to be intuitively true for walleye, but it seems to be spurious for bowfin. Factor 3 showed the association of most coolwater species with lakes of cooler climate, higher transparency, and greater depth. Factor 4 indicated a combination of characteristics--principally denser macrophytes (the climate loading factor was -0.3 in the pounds per acre analysis but 0.0 in the numbers per acre analysis)--which favored bluegills, northern pike, and largemouth bass more than any other factor. The densities of black crappie and carp were associated with factor 6, which was characterized by warmer climates and higher turbidity.

Another technique, cluster analysis, was used to determine groupings of species based on the correlation among their abundance indices (pounds per acre seined). Thus, species which usually occur in the same lakes in parallel amounts would be the most closely clustered. The resulting clusters were about as expected, with the two basic groups of warmwater and coolwater species (Table 3). A subgroup of warmwater fish was composed of those species whose distribution is limited to the more southerly part of Michigan; this subgroup was noted earlier. Largemouth bass and carp were distant members of the warmwater group--the largemouth because it was well represented in nearly all study lakes, the carp because its abundance was not closely linked to that of other fish. The strongest pairing was between rock bass and smallmouth bass; their simple correlation coefficient was 0.63. Unexpectedly, the northern pike was grouped with the warmwater panfish rather than with the coolwater species. However, the pike was grouped with the coolwater fish in a cluster analysis which used percent composition rather than pounds per acre.

Principal component and canonical analyses provided no additional insight and were not useful for reliably sorting lakes or fish communities into groups. However, cluster analysis based on correlations in percent species composition was useful for determining which lakes had the most similar communities. The cluster analysis sorted the lakes and arranged them sequentially, essentially on the basis of the most abundant species.

Intraspecific relationships.--On the species population level, some logical relationships emerged among abundance, growth, and size structure when lakes were contrasted (Table 4). Lakes in which fish were growing rapidly had the highest proportions of large-sized bluegill, pumpkinseed, yellow perch, black crappie, largemouth bass, northern pike, smallmouth bass, and walleye. The correlation coefficient between growth index and percent of large-sized fish ranged from +0.31 to +0.73 for each of these species. This reinforces the widely held opinion that slow-growing populations usually have relatively small fish, and vice versa.

Growth, in turn, was negatively related to abundance for most of the species (Table 4). Abundance was expressed as percent of the total weight of fish caught in Table 4, but similar results were obtained using pounds per acre or numbers per acre. The negative relationship between growth and abundance which emerged by comparing different populations of a species is interpreted as a reflection of density dependence within each population. Pumpkinseed and yellow perch seemed to be exceptions in this data set, but the literature indicates that growth is usually density dependent for all fish species.

In general, there were corresponding negative relationships between abundance and the proportion of large fish in the populations (Table 4). But the correlations were weak, and largemouth bass 10 inches and larger were a significant exception.

On the community level, a relationship between bluegills and piscivorous species was detected. Growth of bluegills was somewhat better in communities with a high proportion of piscivors ($r = 0.20$).

Fishing quality.--Some of the study lakes reputedly provided good sport fishing, others average or poor. Certainly the rankings were subjective. They may not have been applied consistently, may have reflected a temporary condition rather than the long-term norm, or may have been true of only some of the species (at 14 lakes it was reported bluegill fishing was poor due to bluegill overabundance and small average size, but that largemouth bass angling was good). Nevertheless, the differences in fishing quality appeared large and important enough to fisheries management to merit analysis. Presumably, the overall fishing quality of a lake was determined mainly by the most abundant species (usually bluegill, occasionally yellow perch, bass, or other species).

Fishing quality was examined in relation to the composition of the fish communities, the size structure and growth of species populations, and the physical characteristics of the lakes. The data were analyzed by discriminant analysis, and by simply comparing means and ranges of the variables.

Linear discriminant analysis, using percent species composition and the indices of growth and size structure for each species population (a total of 31 variables), correctly ranked the fishing in 85 out of 109 lakes (78%). Some of the variables were more powerful discriminators than others, but useful predictions could not be obtained with fewer variables. When only bluegill growth and yellow perch growth were considered, the predictions matched the reported rankings for 26% of the poor lakes, 29% of the average lakes, and 55% of the good fishing lakes. The failure to achieve more accurate predictions is attributed to a combination of misrankings on the field reports, unrepresentative samples of fish populations, influences of unmeasured factors on fishing success (e.g., differences among populations in vulnerability to anglers), and an imperfect statistical model.

The characteristics of poor, average, and good fishing lakes are described by region in Tables 5 and 6. The differences among these groups of lakes were not clear-cut because the ranges of the variables overlapped, but there were some statistically significant differences in means and some general tendencies.

Good lakes had a higher proportion of their fish biomass in piscivors than did poor lakes (means of 33 and 36% versus means of 17 and 21%, for regions III and II, respectively), mostly due to the proportions contributed by largemouth bass (means of 22 and 26% versus means of 11 and 12%). Also, good fishing lakes had faster growing bluegills (mean growth indices of 0.0 and 0.1 versus -0.9 and -0.8), higher percentages of pumpkinseeds over 6.0 inches long (17 and 27% versus 3 and 9%), and for Region III, higher percentages of bluegills exceeding lengths of 6.0 inches (25% versus 9%) and 8.0 inches (1.3% versus 0.4%). Furthermore, there were tendencies for the better fishing lakes to have lower proportions of bluegill, carp, and white sucker, better growth of panfish but poorer growth of bass and pike, and size structures skewed toward larger panfish but smaller bass and pike.

Environmentally, the better fishing lakes were often deeper and clearer, had more moderate densities of macrophytes, and had a layer of cool and oxygenated water in summer (Tables 5, 6, and 7). Good fishing occurred in about 50% of the lakes of oxygen type 3 (moderately productive, stratified, with a layer of both cool and oxygenated water in midsummer). By contrast, good fishing was found in less than 20% of the type 4 lakes (stratified, cool layer low in oxygen in midsummer) or of the type 5 lakes (unstratified). About half of the unstratified lakes provided poor fishing. Type 4 and 5 lakes comprised 70% of the 20 lakes reputed to have a problem with excessive numbers of small bluegills and 91% of the 11 lakes with "too many" carp. On the other hand, excessive white sucker populations (6 lakes) were as frequent in types 2 and 3 as in type 5.

Certain characteristics of fish communities and bluegill populations were somewhat useful for classifying fishing quality of the study lakes (Table 8). The criteria given for bluegill populations apply only to those lakes in which bluegills made up at least 20% of the total fish biomass. Poor fishing (sometimes average, never good) was the rule in lakes in which: (1) white sucker or carp exceeded 50% of the biomass, (2) bluegill plus pumpkinseed exceeded 78% of the biomass, or (3) minnows plus chubsucker plus warmouth exceeded 15% of the biomass. Of the lakes in which piscivors were 20% or more of the biomass, 39% provided good fishing, 38% average, and only 23% poor. Good or average fishing was likely if the lake produced any 8-inch bluegills, if 6.0-inch and larger bluegills made up 6% or more of the population (the seines captured bluegills as small as about 3 inches), or if bluegill growth was average or better. These criteria, while not complete or definitive, may be applied for ranking lakes throughout Michigan.

Table 1.--Species composition in percent of total weight caught, and catch per acre in numbers and pounds, for lakes seined in Region II (< 1800 growing degree days F) and Region III (≥ 1800 growing degree days F).

Species	Region II [a]				Region III [b]			
	Percent composition		Mean catch per acre		Percent composition		Mean catch per acre	
	Mean	Range	Number	Pounds	Mean	Range	Number	Pounds
Bluegill *Lepomis macrochirus*	36	0-90	284	18	41	tr-83[d]	308	20
Largemouth bass *Micropterus salmoides*	18	0-86	12	6	16	0-84	15	5
White sucker *Catostomus commersoni*	11	0-86	3	3	2	0-54	1	1
Carp *Cyprinus carpio*	3	0-51	tr	1	11	0-92	1	5
Yellow perch *Perca flavescens*	9	tr-69	76	3	7	0-41	42	3
Northern pike *Esox lucius*	6	0-37	2	2	4	0-45	1	1
Pumpkinseed *Lepomis gibbosus*	5	0-38	22	2	5	0-35	32	3
Black crappie *Pomoxis nigromaculatus*	3	0-35	12	2	6	0-49	18	3
Smallmouth bass *Micropterus dolomieui*	3	0-46	1	1	tr	0-23	tr	tr
Rock bass *Ambloplites rupestris*	2	0-13	2	tr	1	0-19	1	tr
Walleye *Stizostedion vitreum*	1	0-52	tr	tr	tr	0-5	tr	tr
Bullhead *Ictalurus* spp.	1	0-9	1	tr	1	0-11	1	tr
Minnows Cyprinidae [c]	1	0-22	5	tr	1	0-17	10	1
Grass pickerel *Esox americanus vermiculatus*	tr	0-2	tr	tr	1	0-4	1	tr
Warmouth bass *Lepomis gulosus*	tr	0-tr	tr	tr	1	0-12	4	tr
Lake chubsucker *Erimyzon sucetta*	tr	0-3	tr	tr	1	0-17	3	1
Bowfin *Amia calva*	tr	0-12	tr	tr	tr	0-8	tr	tr
Gar *Lepisosteus* spp.	tr	0-1	tr	tr	1	0-72	tr	tr
Total	100		422	42	100		440	45

[a] For Region II, percent composition data are for 81 lakes and catch per acre data are for 77 lakes. [b] For Region III, percent composition data are for 148 lakes and catch per acre data are for 144 lakes. [c] "Minnows" include cyprinids (except carp) and, rarely, darters (Etheostomatinae). [d] tr = trace = less than 0.5.

Table 2.--Average species composition in percent by weight for seven subtypes of fish communities in 229 lakes. Lakes in which largemouth bass, carp, or white sucker made up 50% or more of the total biomass were sorted out first, then the remaining lakes were grouped according to the percentage of bluegills.

Species	Species, percentage of community biomass, and number of lakes (in parentheses)						
	Largemouth bass	Carp	White sucker	Bluegill			
	50-86% (13)	50-92% (15)	50-86% (10)	0-24% (36)	25-49% (63)	50-74% (75)	75-90% (17)
Bluegill	11	10	4	10	37	61	80
Pumpkinseed	3	1	2	6	6	7	3
Black crappie	1	5	1	6	7	5	1
Bullheads	1	1	tr	1	1	1	tr
Grass pickerel	1	tr	tr	tr	1	tr	tr
Minnows	tr	1	3	1	2	1	tr
Lake chubsucker	1	tr	0	1	1	1	tr
Warmouth	tr	tr	tr	tr	1	tr	tr
Bowfin	1	tr	tr	1	1	tr	0
Largemouth bass	68	5	7	17	18	13	10
Carp	2	67	tr	11	5	1	0
Northern pike	2	1	2	10	6	3	2
Yellow perch	5	5	2	17	9	5	3
Rock bass	1	tr	2	2	1	1	tr
Smallmouth bass	1	tr	5	5	1	tr	0
Walleye	0	0	4	2	tr	tr	0
White sucker	1	1	65	6	3	1	1

Table 3.--Associations among certain environmental characteristics and species abundance (measured in pounds caught per acre seined) as determined by factor analysis, and associations among species as determined by cluster analysis.

Variable	Factor analysis (126 lakes) Scaled factor loadings				Cluster analysis (221 lakes)
	Factor 1	Factor 2	Factor 3	Factor 4	
Environmental characteristic					
Area	0.0	0.8	-0.2	0.1	
Maximum depth	-0.2	-0.1	0.2	0.0	
Macrophyte index	0.4	0.0	0.0	0.3	
Secchi index	-0.1	-0.2	0.3	0.1	
Climate index	0.4	-0.3	-0.2	-0.3	
Abundance					
Bluegill	0.3	-0.2	0.2	0.6	
Pumpkinseed	0.4	-0.1	0.3	0.3	
Black crappie	0.1	0.1	-0.1	0.2	
Northern pike	0.2	0.2	0.1	0.6	
Bullheads	0.5	0.2	0.2	-0.1	
Grass pickerel	0.6	-0.2	0.1	0.0	
Minnows	0.6	0.1	0.2	-0.3	
Lake chubsucker	0.8	0.1	0.2	-0.3	
Warmouth	0.5	0.1	0.0	-0.2	
Bowfin	0.4	0.6	-0.1	0.0	
Largemouth bass	0.1	-0.3	0.1	0.4	
Carp	0.0	0.0	-0.2	-0.2	
Yellow perch	-0.0	0.0	0.5	-0.1	
Rock bass	-0.2	0.3	0.7	0.0	
Smallmouth bass	-0.3	0.2	0.7	-0.2	
Walleye	-0.1	0.7	-0.2	0.0	
White sucker	-0.1	0.1	0.2	-0.1	
Percent variance (cumulative)	13	22	30	37	

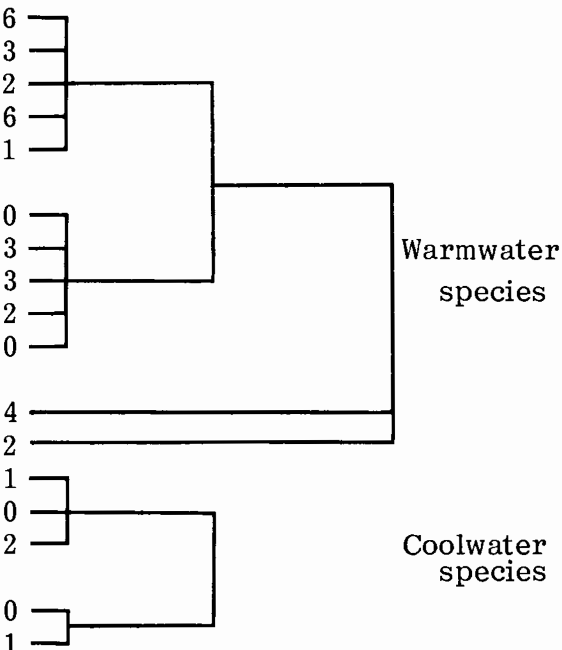

Table 4.--Simple correlation coefficients among indices of growth, population abundance (as percent of total fish weight), and size structure of the population (as percent of the population equal to or larger than a certain length) for each of eight species of fish. The number of lakes sampled is in parentheses.

Species	Growth	Population size structure (equal to or larger in inches)						
		6.0	7.0	8.0	10.0	13.0	15.0	20.0
Bluegill (166)								
Abundance	-0.45*	-0.20*	...	-0.11	...	...	...	...
Growth		0.40*		0.17*				
Pumpkinseed (132)								
Abundance	0.02	-0.06	...	...	...	...	...	...
Growth		0.42*						
Yellow perch (154)								
Abundance	0.06	...	-0.17*	...	...	...	...	...
Growth			0.45*					
Black crappie (94)								
Abundance	-0.13	...	0.06	...	...	...	...	...
Growth			0.40*					
Largemouth bass (132)								
Abundance	-0.06	...	...	...	0.18*	...	-0.04	...
Growth					0.31*		0.14	
Smallmouth bass (17)								
Abundance	-0.41	...	...	...	-0.24	...	...	...
Growth					0.45*			
Northern pike (48)								
Abundance	-0.17	...	...	...	...	...	...	0.08
Growth								0.60*
Walleye (5)								
Abundance	-0.70	...	...	...	...	-0.18	...	...
Growth						0.73		

* Statistically significant at 0.05 level or less.

Table 5.--Species composition of the fish communities (as percent of total weight), size structure of the species populations (as percent of the number caught equal to or exceeding the indicated lengths in inches), growth indices (as deviation in inches from the state average), and physical characteristics of Region II lakes with poor, average, or good sport fishing. The number of lakes sampled is in parentheses.

Species	Mean			Range		
	Poor	Average	Good	Poor	Average	Good
	Species composiition					
	(22)	(22)	(19)			
Bluegill	39	35	37	0-87	0-90	1-73
Pumpkinseed	5	6	3	0-23	0-16	tr-8
Yellow perch	8	12	8	0-69	0-49	tr-39
Black crappie	4	1	5	0-35	0-7	0-32
Rock bass	1	2	1	0-4	0-13	0-4
Largemouth bass	11	21	26	0-39	0-74	1-86
Smallmouth bass	2	4	3	0-16	0-17	0-46
Northern pike	7	5	6	0-37	0-27	0-23
Walleye	1	4	tr	0-17	0-52	0-9
Grass pickerel	tr	tr	tr	0-2	0-tr	0-tr
Bullheads	1	tr	1	0-5	0-1	0-7
Minnows	2	tr	1	0-18	0-1	0-3
Carp	4	0	2	0-51	0	0-28
Warmouth	tr	0	tr	0-tr	0	0-tr
Chubsucker	tr	tr	0	0-tr	0-3	0
White sucker	16	9	6	0-83	0-68	0-31
Bowfin	1	tr	1	0-10	0-2	0-12
P/t [a]	21	35	36	5-51	6-74	5-95
	Size structure					
Bluegill	(21)	(21)	(19)			
6+	14	31	23	1-83	3-100	4-64
8+	4	3	2	0-43	0-46	0-13
Pumpkinseed	(20)	(20)	(19)			
6+	9	23	27	0-46	2-94	0-75
Yellow perch	(22)	(22)	(19)			
7+	21	19	34	0-67	0-88	0-100
Black crappie	(12)	(11)	(12)			
7+	34	41	75	0-81	0-100	3-100
Rock bass	(8)	(17)	(11)			
6+	39	51	51	0-100	0-100	4-100
Largemouth bass	(21)	(21)	(19)			
10+	49	30	38	2-100	0-98	4-92
15+	20	7	5	0-100	0-33	0-19

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Table 5.--continued.

Species	Mean			Range		
	Poor	Average	Good	Poor	Average	Good
Size structure, continued						
Smallmouth bass	(8)	(12)	(9)			
10+	52	27	28	12-100	0-100	11-100
15+	5	15	14	0-13	0-100	0-100
Northern pike	(18)	(15)	(14)			
20+	40	45	22	0-100	0-100	0-88
Walleye	(2)	(4)	(4)			
13+	100	36	54	100	6-100	17-100
Growth						
Bluegill	-0.9	-0.4	0.0	-2.1	-1.6	-1.4
	(18)	(18)	(16)	to 0.7	to 1.6	to 1.5
Pumpkinseed	-0.4	-0.1	0.0	-1.6	-1.2	-1.4
	(12)	(13)	(12)	to 1.2	to 0.8	to 0.8
Yellow perch	-0.6	-0.5	0.3	-1.6	-1.2	-1.6
	(16)	(14)	(9)	to 0.5	to 0.5	to 2.9
Black crappie	-0.5	-0.5	0.3	-1.3	-1.9	-0.7
	(7)	(6)	(6)	to 0.2	to 0.6	to 1.8
Largemouth bass	-0.6	-1.1	-0.4	-2.4	-2.5	-1.6
	(6)	(15)	(10)	to 1.0	to 0.6	to 1.1
Smallmouth bass	-2.3	-0.9	-0.8	-2.3	-1.4	-2.0
	(1)	(7)	(3)		to -0.3	to 1.4
Northern pike	-1.0	0.1	-0.7	-3.5	-4.9	-3.6
	(7)	(5)	(6)	to 1.1	to 3.1	to 2.5
Walleye	1.6	-1.0	0.8	1.6	-1.5	0.8
	(1)	(2)	(1)		to -0.6	
Physical characteristics						
Area (acres)	243	709	1316	14-1972	13-5660	62-20,044
	(22)	(22)	(19)			
Maximum depth (feet)	37	39	51	10-95	13-152	8-85
	(22)	(22)	(18)			
Macrophytes, as rank	3.4	3.2	3.2	1-5	2-4	1-5
	(18)	(22)	(17)			
Secchi disk (feet)	10	10	12	6-15	3-15	4-24
	(17)	(20)	(16)			
Oxygen, as type	4.1	4.2	3.4	2-5	3-5	1-5
	(20)	(20)	(17)			

[a] P/t = percentage of piscivorous species of the total weight (see text).

Table 6.--Species composition of the fish communities (as percent of total weight), size structure of the species populations (as percent of the number caught equal to or exceeding the indicated lengths in inches), growth indices (as deviation in inches from the state average), and physical characteristics of Region III lakes with poor, average, or good sport fishing. The number of lakes sampled is in parentheses.

Species	Mean			Range		
	Poor	Average	Good	Poor	Average	Good
		Species composition				
	(38)	(40)	(24)			
Bluegill	43	44	35	1-83	2-82	4-69
Pumpkinseed	5	5	3	0-23	0-35	0-12
Yellow perch	7	7	8	0-36	0-23	1-23
Black crappie	6	5	6	0-25	0-22	0-40
Rock bass	tr	tr	1	0-5	0-6	0-19
Largemouth bass	12	17	22	0-70	1-84	4-76
Smallmouth bass	0	tr	tr	0	0-9	0-3
Northern pike	3	3	6	0-26	0-29	0-22
Walleye	tr	tr	tr	0-tr	0-1	0-1
Grass pickerel	1	1	1	0-4	0-2	0-4
Bullheads	1	tr	1	0-6	0-3	0-5
Minnows	2	1	tr	0-13	0-5	0-4
Carp	17	8	5	0-82	0-92	0-47
Warmouth	1	1	1	0-12	0-7	0-5
Chubsucker	1	1	1	0-17	0-13	0-6
White sucker	tr	4	4	0-9	0-54	0-45
Bowfin	1	tr	tr	0-8	0-6	0-4
P/t [a]	17	23	33	1-71	2-88	4-78
		Size structure				
Bluegill	(38)	(40)	(24)			
6+	9	20	25	0-67	0-96	1-83
8+	tr	1	1	0-1	0-7	0-6
Pumpkinseed	(36)	(37)	(23)			
6+	3	10	17	0-22	0-67	0-45
Yellow perch	(37)	(38)	(24)			
7+	18	29	29	0-100	0-100	0-93
Black crappie	(38)	(32)	(21)			
7+	40	52	60	0-100	0-100	0-100
Rock bass	(13)	(16)	(14)			
6+	57	35	57	6-100	0-100	0-100
Largemouth bass	(38)	(40)	(24)			
10+	26	26	24	0-89	4-100	3-86
15+	8	6	3	0-50	0-73	0-17
Smallmouth bass	(0)	(2)	(4)			
10+		30	69		5-54	0-100
15+		10	38		1-18	0-67
Northern pike	(19)	(20)	(18)			
20+	38	56	44	0-100	0-100	0-100
Walleye	(1)	(3)	(2)			
13+	0	38	100	0	0-100	100

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Table 6.--continued.

Species	Mean			Range		
	Poor	Average	Good	Poor	Average	Good
			Growth			
Bluegill	-0.8 (37)	-0.3 (36)	0.1 (24)	-2.1 to 0.7	-1.2 to 0.8	-0.7 to 0.8
Pumpkinseed	-0.5 (25)	-0.1 (25)	0.0 (14)	-1.5 to 0.2	-0.9 to 1.5	-0.8 to 1.1
Yellow perch	-0.3 (21)	-0.1 (29)	0.3 (22)	-1.8 to 1.6	-1.9 to 1.2	-1.0 to 1.7
Black crappie	-0.7 (20)	-0.1 (20)	0.0 (11)	-2.4 to 0.6	-2.2 to 1.7	-1.4 to 1.4
Largemouth bass	-0.2 (18)	-0.6 (28)	-0.5 (19)	-1.3 to 1.6	-2.3 to 1.9	-2.3 to 1.9
Smallmouth bass		0.6 (1)			0.6	
Northern pike	-0.6 (6)	-1.7 (3)	-1.0 (6)	-3.1 to 1.9	-2.2 to -1.2	-3.5 to 2.5
Walleye		-0.1 (1)	2.7 (1)		-0.1	2.7
			Physical characteristics			
Area (acres)	193 (38)	263 (40)	233 (24)	15-1050	46-2680	30-630
Maximum depth (feet)	36 (38)	43 (38)	45 (23)	8-118	11-90	18-71
Macrophytes, as rank	3.5 (24)	3.7 (27)	3.6 (14)	1-5	3-5	3-5
Secchi disk (feet)	8 (22)	9.4 (26)	9 (17)	1-13	4-14	5-14
Oxygen, as type	4.1 (27)	4.0 (26)	3.8 (17)	2-5	2-5	3-5

[a] P/t = percentage of piscivorous species of the total weight (see text).

Table 7.--Percent of study lakes of a given oxygen-thermal type with poor, average, or good fishing.

Oxygen-thermal type[a]	Number of lakes	Fishing quality (%)			
		Poor	Average	Good	Total
2	7	43	29	28	100
3	27	26	22	52	100
4	53	36	45	19	100
5	41	46	37	17	100

[a] Oxygen-thermal types for midsummer conditions (Schneider 1975):

Type 2--Stratified lakes in which dissolved oxygen falls to 2 ppm in the hypolimnion.

Type 3--Stratified lakes in which dissolved oxygen falls to 2 ppm between the 5-foot level of the thermocline and the top of the hypolimnion.

Type 4--Stratified lakes in which dissolved oxygen falls to 2 ppm between the bottom of the epilimnion and the 5-foot level of the thermocline.

Type 5--Unstratified lakes.

Table 8.--Percent of study lakes meeting selected fish community and population criteria which provide poor, average, or good fishing.

Criteria	Number of lakes	Fishing quality (%) Poor	Average	Good	Total
Community composition (percent by weight)					
White sucker = 50% or more	7	57	43	0	100
Carp = 50% or more	11	82	18	0	100
Bluegill + pumpkinseed = 78% or more	17	65	35	0	100
Minnows + chubsucker + warmouth = 15% or more	4	75	25	0	100
Piscivors (P/t) = 20% or more	82	23	38	39	100
Bluegill size structure (percent by number) [a]					
6.0 inches and larger = 6% or more	78	21	43	36	100
8.0 inches and larger = greater than 0%	52	10	48	42	100
Bluegill growth (deviation from state average) [a]					
Growth index = greater than -1.0	69	22	42	36	100
Growth index = 0.0 or greater	25	8	44	48	100

[a] Applies only to lakes in which bluegills were more than 20% of the total fish biomass.

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