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during this period which indicates that the diet is adequate in all respects. In this group of experiments the vitamin B complex or some components of it, was destroyed by heating the basic tryptone medium to 120° C. for one hour at pH 9.6. When the pH was readjusted to 6.0 this medium would not support the growth of *C. striatum*. However, when thiamin chloride was added in concentrations as low as 1:10,000,000 growth was equal to that of the untreated control. Increased concentrations of thiamin up to 1:2000 produced no better effects although no harmful results were noted. These experiments demonstrated conclusively that thiamin chloride was an essential nutritional factor in the diet of this protozoan.

The fact that thiamin was an essential growth factor for *C. striatum* led the writer to speculate as to whether or not other members of the vitamin B complex might not also be important. Such investigation is under way at present and so far it has been shown that neither riboflavin nor a vitamin B_6 concentrate is able to supplant thiamin. Whether or not these substances are essential for the continued existence of this ciliate has not yet been determined.

THE GROWTH RATE OF WALL-EYED PIKE (*STIZOSTEDION VITREUM* (MITCHILL) IN VARIOUS LAKES OF MINNESOTA *

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One of the important guides for modern fish propagation and management is the growth rate of fishes. In some lakes, the fishes caught by fishermen are smaller than those caught in other lakes and this raises the question of whether fish grow at the same rate in all lakes. The fish culturist must know the rate of growth and the length of time necessary for various species of game fish to reach adult size. The study of the rate of the growth of fishes was undertaken at the University of Minnesota several years ago and has been continued with the cooperation of the Department of Conservation, the N.Y.A., the W.P.A., the C.C.C., the United States Forest Service, and other agencies. Species of all common fishes have been studied, but emphasis has been placed on the study of important game fishes, such as the wall-eyed pike.

Each scale of a fish has characteristic marks from which the age, growth rate, and other details of the life history may be ascertained.

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A typical scale has a number of concentric rings of growth, called circuli, formed every three or four weeks. When the growth is slow during the winter, the rings are close together forming a winter ring or annulus. By counting the annuli, the age of the fish may be determined. Since the growth of the scale is proportional to the growth of the fish, the length of the fish may be computed for any previous age. Van Oosten's methods (1929) were used in the laboratory work.[1]

One of the most important fish in the state, particularly from the angler's viewpoint, is the wall-eyed pike, *Stizostedion vitreum* (Mitchill). In the period from 1935, when the studies were started, until the end of 1937, scales from 3,676 wall-eyed pike were collected from eighty-one lakes and streams in all parts of Minnesota. The great majority, however, came from lakes in the Superior and Chippewa National Forests. The largest wall-eyed pike taken in these collections was 34.7 inches long (total length) and weighed 7.5 pounds. It was in its twelfth summer, and came from Sand Lake, near Virginia. The oldest was in its fourteenth summer. It was 32.5 inches long and came from Little Birch Lake, Stearns County.

The growth rates of individual wall-eyed pike varied considerably. Rapid growing individuals reached a standard length of 12 inches early in the third year, while some slower growing individuals did not reach this length until late in the sixth year. Just as there are tall people and short people in the same town, there are fast-growing and slow-growing wall-eyed pike in the same lake. Because of this, care should be used in interpreting data from small samples.

However, despite some extreme individual differences, the majority of the fish within a single lake have about the same growth rate. A comparison of the average growth rates for the various lakes shows that in some lakes the wall-eyed pike grow rapidly, while in other lakes they grow slowly. The physical, chemical, and biological conditions of these lakes are being studied in an attempt to determine the conditions that affect the growth of this species.

In one lake the fish attained a standard length of 12 inches in an average of over five years, while in another lake the fish attained this length in half this time. Even neighboring lakes had different average growth rates. For example, in Big Pelican Lake, Ottertail County, it took an average of 4.10 years for a wall-eyed pike to grow to a standard length of 12 inches, while in nearby Ottertail Lake it took only 3.45 years for the fish to reach this length. In Lower Comstock Lake, Saint Louis County, wall-eyed pike in 4.69 years attained a length of 12 inches, while in nearby Sand Lake the pike attained this length in 3.31 years. These differences of growth in lakes so similar in general conditions may not be due to differ-

[1] Van Oosten, John, 1929. Life history of the lake herring (*Leucichthys artedi* (LeSueur) of Lake Huron as revealed by its scales, with a critique of the scale method. Bulletin U. S. Bur. Fish., 44:265–428.

ences in physical and chemical environment but may be due to differences in population balances which increase or decrease the competition.

As some of the fishes used in this study were secured by gill-netting and others by angling, there was an opportunity to compare these two methods of sampling. Gill-nets were found to be more selective, in that they ordinarily retained fish of only a certain size. The variation in length of the fishes of a gill-net catch covered a range of less than seven inches, while the variation in length of the fishes from an angling catch covered a range of over 11 inches. For example, 63 wall-eyed pike collected in 1936 by gill-nets from Lake Winnibigoshish were from 11 inches to 19 inches long, while in 1937, 109 wall-eyed pike caught by anglers from the same lake ranged from 10 to 22 inches in total length. Thus a gill-net is selective and tends to catch fish within certain size limits. Hile (1936)[2] found similar results in gill-net catches of cisco from Wisconsin lakes. Angling is partially selective, usually not capturing the smallest individuals, but this selectivity is not so noticeable as in gill-netting.

The effect of this selectivity in gill-net catches was noted in the data compiled from such samples. The younger fish appeared to be more rapid growing than the older fish. This was because only the larger and faster growing individuals in the lower age classes were caught. Thus, the younger age classes were not represented in the catches by individuals of average growth. The reverse was true in the older age classes where only the smaller individuals were caught. These characteristics are usually referred to as Lee's phenomenon of apparent change of growth.[3] Because of this selectivity it was found advisable to use only the middle and best represented age classes in certain gill-net samples for determining average growth rates.

In other species of fish, it has been noted that the growth in the southern part of the state is more rapid than in the northern part, probably in correlation with the growing season. This has been pointed out by Bennett (1937)[4] for the large-mouthed black bass in Wisconsin, and by Hubbs and Cooper (1935)[5] for various sunfish in Michigan. However, this does not seem to be true for the wall-eyed pike in Minnesota, as the growth in the northern half of the state was not significantly slower than that in the southern half. The growth of the wall-eyed pike may not be influenced by the limited differences in the growing season within Minnesota. There

[2] Hile, Ralph, 1936. Age and growth of the cisco *(Leucichthys artedi)* in the lakes of northeastern highlands of Wisconsin. Bulletin U. S. Bur. Fish., 48:211–317.

[3] Lee, R. M., 1912. An investigation into methods of growth determination in fishes. Conseil. Perm. Explor. de la Mer. Publu. de Circon. 63:36.

[4] Bennett, George W., 1937. The growth of the large-mouthed black bass *(Huro salmoides)* in the waters of Wisconsin. Copeia, 27:104–118.

[5] Hubbs, Carl L. and Cooper, Gerald P., 1935. Age and growth of the long-eared and green sunfish in Michigan. Papers Michigan Acad. of S. A. & L., 20:669–696.

are, however, as yet too few fish available from the southern region to draw any final conclusions.

Wall-eyed pike are not native in most of the lakes in the eastern part of Cook County but have been introduced there in recent years. Although the productivity of these lakes, as measured by chemical and biological surveys was very low, the growth rate for wall-eyed pike was very high. In this area the wall-eyed pike in five of the nine lakes investigated reached an average length of 12 inches before they were three years old. There are only five other lakes in the state in which the growth was as rapid.

It has often been noted that successful introduction of a species into a new habitat is followed by exceptionally rapid growth. This is probably due to lack of competition within the species and perhaps also due to lack of specific enemies and parasites. Wall-eyed pike grow very slowly in similar lakes nearby where they are native, indicating that the rapid growth is a result of recent introduction.

	Total Length in Inches at End of Each Year							
	1	2	3	4	5	6	7	8
Native	4.3	8.3	11.6	14.7	18.2	20.6	23.8	26.0
Introduced	5.0	9.3	13.4	16.6	19.2	23.9	24.9	27.7

When the competition has increased in these Cook County lakes and when the wall-eyed pike population has reached a somewhat stable condition, the growth rates in these lakes will probably be quite similar to those in other lakes where they are native.

Scale and growth studies of wall-eyed pike have been undertaken in a number of other localities. The average growth rates from these studies are given below.

	Number Examined	Average Total Length in Inches at Each Year								
		1	2	3	4	5	6	7	8	9
Bajkov (1928)										
Winnipeg[6]		7.3	10.5	13.2	15.0	16.4	17.8	18.9	19.6	19.9
Hart (1928)										
Nipigon	84	5.6	7.7	9.5	12.6	14.2	14.4	15.3	18.6	19.5
Abitibi[7]	33		8.0		11.5	11.9	12.8	14.0	17.6	17.8
Juday-Schloemer										
Wisconsin (1938)[8]	766			14.3	15.0	16.9	18.4	19.9	21.2	22.9
Minnesota										
Average	6599	4.6	8.6	12.0	15.0	18.1	20.5	22.9	25.2	26.7

[6] Bajkov, Alexander, 1930. Fishing industry and fisheries investigations in prairie provinces. Trans. Amer. Fish. Soc., 60:215–237.

[7] Hart, John L., 1928. Data on the rate of growth of pike perch *(Stizostedion vitreum)* and sauger *(Stizostedion canadensis)* in Ontario, University of Toronto Studies, Publ. Ontario Fish. Research Lab., No. 34, 45–55.

[8] Juday, Chancey & Clarence L. Schloemer, 1938. Growth of game fish in Wisconsin waters, Fifth report. Notes from Limnological Laboratory of the Wis. Geol. and Nat. Hist. Survey, April, 1938, 1–26.

A comparison of these growth rates shows that the Minnesota average is somewhat higher than that of the others, except for the first few years. These data for the earlier years are probably not comparable because these other growth rates were based not on calculated lengths, but only upon actual lengths. As these other collections consisted largely of adult fishes, the data for the first, second and third years were based upon comparatively few fish and it is likely that these were not average individuals.

The growth of wall-eyed pike in Minnesota waters, therefore, seems to be more rapid than that in other waters that have been studied to this time. This does not mean that the growth of pike in all of the Minnesota lakes is more rapid than that in lakes studied elsewhere. The growth rate in some Minnesota lakes is slower than that in Lake Abitibi, Ontario, which had the slowest rate of any of the lakes in the investigations mentioned. However, the growth rate for wall-eyed pike in most Minnesota lakes is more rapid than that reported elsewhere.

This study shows that, although the growth rate of wall-eyed pike varies in individuals, there is a tendency for most of the wall-eyed pike within a lake to have similar growth rates. The factors which are responsible for differences in growth rates may be either hereditary or environmental. Although practically nothing is known about heredity as a factor in the growth of wall-eyed pike, it is highly probable that environment plays the more important role.

Other studies have shown that heavy or crowded populations of wall-eyed pike usually show low average growth rates because of increased competition. High average growth rates are shown by populations newly introduced into virgin waters where competition by their own species is least. Food undoubtedly plays some part in determining rate of growth. These conditions indicate that the growth rate of a wall-eyed pike population is greatly influenced by the density of the population and the resulting competition for the necessities of life.

Summary

1. Wall-eyed pike from various parts of Minnesota show very little difference in their average rates of growth.

2. Certain individual wall-eyed pike show considerable range in their growth rate within the same lake, although most of the fish show a growth rate close to average.

3. Different lakes, regardless of the region of the state, may show distinct differences in average growth rate for wall-eyed pike probably due to differences in environmental conditions.

4. Wall-eyed pike introduced into suitable lakes which previously contained no native wall-eyed pike grow faster than elsewhere.