THE INFLUENCE OF CERTAIN ENVIRONMENTAL FACTORS ON THE GROWTH OF NORRIS RESERVOIR SAUGER, "Stizostedion Canadense Canadense" (SMITH)

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INTRODUCTION

The influence of natural conditions upon the growth and abundance of fish populations is seldom evaluated. The lack of such information results usually from the fact that few research projects are continued long enough to collect sufficient data on fluctuating environmental conditions. In other instances an insufficient amount of limnological and meteorological data have been recorded on projects of long duration. In other cases the environmental data have only been recorded during the summer months.

The current use of fishery management techniques such as population manipulation or environmental alteration also increases the need for more information about the effects of variable environmental factors on fish growth and abundance. Valid conclusions from these techniques require that other sources of variation be recognized and estimated. Otherwise, management techniques may be deemed responsible for effects which resulted primarily from environmental changes.

In this paper a few of the factors which the field biologist may have to contend with are discussed. The discussion is, for the most part, incomplete. However, the main purpose of the paper is to create an awareness of these factors.

FIRST-YEAR GROWTH OF SAUGER IN NORRIS RESERVOIR

An age and growth study of 3,393 Norris Reservoir sauger taken over a 13-year period revealed different rates of growth for the various calendar years (Table I). In an effort to determine possible causes for these variations, the limnological and meteorological data which were available for the 13-year span were examined. These data were evaluated in respect to the first-year growth rates of the sauger by means of correlation analysis. The first-year growth rates of the sauger were selected for the following reasons:

(1) The greatest increments in length occurred during the first year of life and it was believed that these increments would best indicate any changes in the annual growing conditions. The multiple effects of several years of growth are also avoided.

(2) These increments were independent of growth incurred in other years. It was found that the growth of the second year was inversely correlated with the growth of the first year.

(3) There was no statistical difference in the standard length of the males and females for the first year of life. The first-year growth rates were similar in the various regions of the reservoir. Genetic differences were not apparent.

THIRTEEN YEAR WATER TEMPERATURE RECORD OF NORRIS RESERVOIR, TENNESSEE

Water temperature data for the 13 years of Norris Reservoir history investigated in this paper were available from the Hydraulic Data Division and the Fish and Game Branch of the Tennessee Valley Authority. Water temperatures of 60° F. were used to demarcate the length of the sauger growing season. Table II gives the approximate date in the spring when the water in the upper part of Norris Lake first attained a temperature of 60° F. at a depth of 0.5 foot. Similar information is presented in this table for the fall season. The elapsed time in days between these two dates is also given for each year.

It was surprising to find that a temperature of 60° F. or higher (at 0.5 foot) occurred in Norris Lake for an average of 30½ weeks a year for the 13 year span from 1937 to 1949. Stroud (1948) listed temperatures of 60° F. or higher at a depth of ten feet for each year from 1937 to 1946. The average elapsed time in weeks in his data is calculated to be approximately 29¾ weeks. Thus, the temperature data recorded at 0.5 foot in depth appears to be indicative of lake conditions.

TABLE I

AVERAGE CALCULATED STANDARD LENGTH AND STANDARD ERROR FOR YEARLING NORRIS RESERVOIR SAUGER ARRANGED BY YEAR CLASS

Year Class	*No. of Fish*	*Millimeters*	
		Calculated Std. Length	*Standard Error*
1937	6	174	..
1938	80	206	4.1
1939	48	162	3.2
1940	618	155	1.2
1941	489	200	1.4
1942	160	192	2.0
1943	114	171	2.7
1944	185	162	2.1
1945	234	173	2.1
1946	242	182	2.0
1947	112	164	2.2
1948	717	157	0.9
1949	229	209	1.6
TOTAL	3,393	175	0.6

TABLE II

APPROXIMATE DATES WHEN THE WATER TEMPERATURES OF NORRIS RESERVOIR REACHED 60° F. AT A DEPTH OF 0.5 FOOT (1937-1949)*

Year	*Season*		*Time in Days*
	Spring	*Fall*	
1937	April 25	November 1	190
1938	April 8	November 20	226
1939	April 15	November 12	211
1940	April 30	November 17	201
1941	April 19	November 20	215
1942	April 12	November 16	218
1943	April 9	November 7	212
1944	April 22	November 12	204
1945	Mar. 26	November 10	228
1946	April 1	November 22	236
1947	April 24	November 12	202
1948	April 30	November 9	193
1949	April 3	November 26	237

* Chiefly interpolated from isodepth charts made available by the Hydraulic Data Division of the Tennessee Valley Authority. Temperatures taken at Highway No. 33 Bridge, Highway No. 25E Bridge, and Norris Dam. 1941 fall data and 1942 spring data estimated from temperature taken at Highway No. 25E Bridge. 1949 data from files of Fish and Game Branch of the TVA.

CORRELATION BETWEEN AGRICULTURAL GROWING SEASON AND LAKE TEMPERATURE

Since the duration of the agricultural growing season in days is sometimes used as an indicator of growing conditions in lakes, a comparison was made between the length in days of the agricultural growing season and the water temperature data on Norris Lake to determine the validity of their association.

Table III compiled from *Climatological Data, Tennessee* (U. S. D. A.) lists the dates of the last freezing temperatures in the spring at Norris, Tennessee, and the dates of the first freezing temperatures in the fall at the same station. The elapsed time in days between these dates is also given.

The coefficient of correlation was computed between the elapsed time in days between spring and fall water temperatures of 60° F. (0.5 ft.) in Norris Lake and the elapsed time in days of the agricultural growing season.

The coefficient of correlation was 0.10 and this value was nonsignificant. Also, the result of correlation analysis between the length of the agricultural growing season in days and the first-year growth of sauger was not significant ($r = 0.10$). In view of these results it is apparent that the practice of evaluating previous environmental conditions in lakes and the duration of fish growing seasons by the use of "time between frosts" is of little value.

TABLE III

FREEZE DATA FOR NORRIS, TENNESSEE, 1937-1949

Year	*Last Freeze in Spring*	*First Freeze in Fall*	*Elapsed Time in Days*
1937	April 12	October 24	195
1938	April 10	October 25	198
1939	April 13	October 16	186
1940	April 13	November 8	209
1941	Mar. 30	November 9	223
1942	April 12	October 27	198
1943	April 16	October 18	185
1944	April 6	October 28	205
1945	Mar. 11	November 4	238
1946	April 13	October 15	185
1947	May 9	November 8	183
1948	April 10	October 21	194
1949	April 25	November 4	193

From *Climatological Data, Tennessee,* U. S. D. A., 1937-1949.

ASSOCIATION BETWEEN WATER TEMPERATURES AND SAUGER GROWTH

The association between the first-year growth of sauger and the elapsed time in days between a temperature of 60° F. at 0.5 foot in depth in spring and fall was determined by calculating the coefficient of correlation. A value of 0.69 was obtained for this coefficient. Fisher's "t" test was applied to test the significance of this coefficient, and it was found that a value greater than this could occur by chance, if the variables had no correlation, less than one percent of the time. A graph illustrating the relationship between growth and temperature is given in Figure 1. This close correlation between water temperatures and growth in fishes is to be expected, but it is seldom recorded and analyzed under natural conditions.

It is realized that other factors are also operating concurrently on sauger growth. The records of year-class abundance indicate that population density had an influence on the rate of growth. However, since the year-class abundance was arbitrarily ranked, multiple correlation analysis was not used to determine its effect on growth.

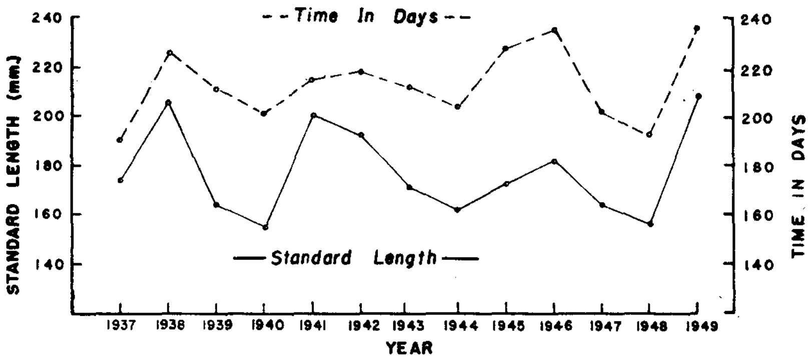

FIGURE 1. Relationship between the standard length of yearling sauger, and the elapsed time between water temperatures of 60°F. in Norris Reservoir, Tennessee.

CORRELATION BETWEEN FIRST-YEAR GROWTH OF SAUGER, AND TIME IN DAYS BETWEEN 50° F. AND 60° F. (0.5 FOOT)

The time in days between water temperatures of 50° F. and 60° F. at 0.5 foot in Norris Reservoir in the spring was determined for the years 1937 to 1949. These data are given in Table IV. In order to determine if the water temperatures at this time of year were associated with the first-year growth of the sauger in the various calendar years, the coefficient of correlation was calculated for these variables. The value of this coefficient was —0.51. The significance of this coefficient was tested by Fisher's "t" test. The probability of obtaining a value numerically greater than 0.51, if no correlation existed between the two sets of varieties, was calculated to be 8 percent. It seems likely that a relationship exists between the variates.

TABLE IV

APPROXIMATE DATES WHEN THE WATER TEMPERATURES OF NORRIS LAKE REACHED 50° F. AND 60° F. AT A DEPTH OF 0.5 FOOT (1937-1949)

Year	*Temperature 50° F.*	*Temperature 60° F*	*Total Elapsed Time in Days*
1937	March 1	April 25	55
1938	March 13	April 8	26
1939	March 8	April 15	38
1940	March 2	April 30	59
1941	April 5	April 19	14
1942	March 22	April 12	21
1943	March 11	April 9	29
1944	March 13	April 22	40
1945	March 4	Mar. 26	22
1946	January 30	April 1	59
1947	March 30	April 24	25
1948	March 5	April 30	56
1949	March 1	April 3	33

A graph of the spring temperatures and first-year growth is given in Figure 2. The inverse relationship between growth and time in days between 50° F. and 60° F. shows a definite trend except for the year 1946.

The correlation coefficient between the length of the growing season (time in days between first 60° F. in spring and last 60° F. in fall) and the time in days required for the water temperature to increase from 50° F. to 60° F. was calculated. The coefficient was —0.35 and this value would be exceeded 24 percent of the time by chance alone. Thus, these temperatures do not appear to be related, and each has its own effect on sauger growth.

The possible ways in which sauger growth may be affected inversely during the spring are as follows:

(1) Lower metabolic rate during prolonged period of time if water temperature increases but slowly.

(2) A greater survival of sauger fry and fingerlings may occur during the years of slowly increasing temperatures. This would result in a greater population density which in turn could be a limiting factor on growth.

(3) It has been observed that the spawning of sauger occurs at a temperature of approximately 50° F. in Norris Lake. It is assumed that the fingerling sauger feed upon plankton until the forage fish spawn. Shortly afterwards, an abundance of food small enough for the fingerling sauger is available and a change in feeding habits ensues. Dendy (1946) reports that Dr. R. W. Eschmeyer observed the spawning of gizzard shad, *Dorosoma cepedianum* (LeSueur), at a temperature of 60° F. in Norris Lake. The author has also observed the same species spawning in Norris Reservoir during 1950 and 1951 at approximately the same temperature. Consequently, it seems logical to expect a slow rate of growth in sauger in years when the lake waters warm slowly. If this period is prolonged between the time of spawning for the sauger and the time of spawning of the forage fishes, it is believed that the period of plankton feeding will be prolonged and the resulting initial slow growth will be reflected in the total growth for the first year of life. If the forage fish spawn shortly after the spawning of sauger has occurred, a short plankton feeding period is indicated for the sauger.

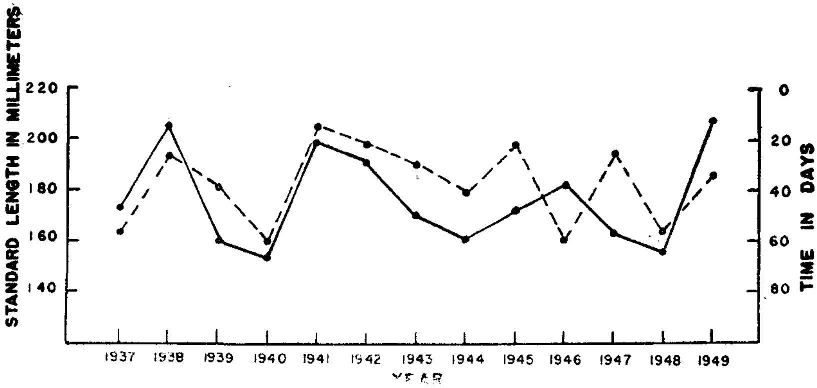

FIGURE 2. Relationship between first-year growth of sauger (solid line) and time in days (broken line) for Norris Reservoir water temperatures to increase from 50°F. to 60°F.

CORRELATION BETWEEN PRECIPITATION AND FIRST-YEAR GROWTH OF SAUGER

Another environmental factor which varied considerably from year to year was the amount of rainfall. Precipitation records have been compiled with great detail by the Hydraulic Data Division of the Tennessee Valley Authority. Table V gives the precipitation in inches at Norris Dam during the months of February to March, from 1937 to 1949,

Since the spawning of sauger may occur from late February to early April in Norris Reservoir, the degree of association between the combined rainfall for February and March and the first-year growth of sauger was determined. The coefficient of correlation between the first year growth and combined February-March precipitation was —0.57. The "t" test showed this coefficient to be significant. The probability of obtaining a correlation coefficient of this magnitude if no correlation existed between the series of variates is less than 4.00 percent.

A graph illustrating the association of February-March rainfall and first-year sauger growth is presented in Figure 3.

TABLE V

MONTHLY PRECIPITATION FOR FEBRUARY AND MARCH IN INCHES AT NORRIS DAM, TENNESSEE (1937-1950)*

Year	Combined February-March Rainfall (Inches)
1937	6.70
1938	7.82
1939	15.57
1940	10.51
1941	3.68
1942	9.12
1943	10.21
1944	17.13
1945	10.17
1946	9.53
1947	5.05
1948	15.10
1949	7.97
1950	9.55

* From *Precipitation in Tennessee River Basin Annual* prepared by the Hydraulic Data Division of the T. V. A.

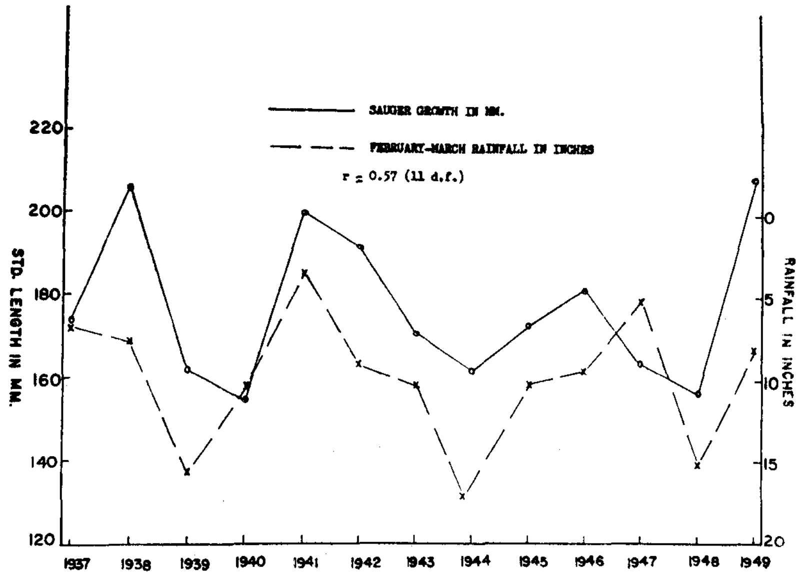

FIGURE 3. Relationship between the first-year growth of sauger and the combined February-March rainfall in inches.

INFLUENCE OF SOLAR RADIATION ON FIRST-YEAR GROWTH OF SAUGER

The percentage of possible sunshine was examined for monthly periods from 1937 to 1949 in reference to the first year growth of sauger. Statistical analysis failed to reveal any correlation between the total annual radiation and growth. Analysis on a monthly basis gave a statistically significant correlation coefficient of 0.60 for the month of November. The amounts of radiation in the other months were not correlated with growth. It is probable that the November correlation coefficient was derived by chance. However, the possibility exists that large amounts of sunshine in November would have the effect of prolonging the growing season.

CORRELATION BETWEEN AIR TEMPERATURES AND FIRST-YEAR GROWTH OF SAUGER

Doan (1942) has suggested the use of air temperatures to indicate monthly variations of water temperatures from normal. He found a significant correlation between average air temperatures and Lake Erie water temperatures for the spring and summer months.

Van Oosten (1929) reached the conclusion that little correlation existed between the growth rate of one-year-old herring and the average annual air temperature.

However, Hile (1941) reported that the total temperature deviation for June and September to be significantly correlated with the growth of rock bass in Nebish Lake, Wisconsin.

Hile (1936) also reported that a correlation did not exist between the differences in the length of the growing season of the cisco and the air temperature.

Air temperatures at Norris Dam were compiled and analyzed in order to determine if any association existed between these temperatures and sauger growth. Both annual and monthly mean air temperatures were examined. However, analysis revealed that these air temperatures were not correlated with the first-year growth of Norris Reservoir sauger.

INFLUENCE OF WATER LEVEL FLUCTUATIONS ON THE FIRST-YEAR GROWTH OF SAUGER

Since Norris Reservoir is a multiple-power storage impoundment, annual fluctuations in water levels occur within years and between years. Stroud (1948) indicated that the growth of black crappie and basses was correlated with the long term cycle of maximum water elevations. His data stressed the increase in growth of young-of-the-year largemouth bass in those years when high-water levels inundated the vegetation which had grown on the exposed lake floor.

The maximum elevations attained annually in Norris Reservoir from 1937 to 1949 are listed in Table VI. In order to determine the effects of water-level fluctuations on the first-year growth of sauger, both graphical and statistical analysis was made on these variables. A definite trend was not evident in the graph. The correlation coefficient was calculated to be 0.40 and the probability of obtaining a coefficient of that magnitude by chance was relatively large. However, a cyclic trend was indicated by the rapid rate of growth which occurred in 1942 and 1949. In each of these years the maximum water level reached a higher elevation than in the three preceding years. However, it should be noted that young-of-the-year sauger also grew rapidly in other, non-cyclic years. Both the 1938 and 1941 year classes attained a greater size than the cyclic 1942 year class. In 1941 the maximum water level for the year was one of the lowest ever recorded. The 1938 water level barely surpassed that of the previous year. In 1945 and 1946 sauger growth increased although the maximum water elevation declined in each of those years.

Another factor which should be considered in relation to growth is the effect of population density. The 1942 and 1949 year classes were estimated to be of very low abundance. The rapid growth attained in these years may have been aided considerably by the decreased competition in a small year-class.

The length of the growing season also complicates the effects of water level fluctuations on growth. Although it appears evident that the inundation of three years vegetation supplied the basic nutrients for the growth increase in 1949, a check of the water temperature data reveals that the 1949 year class also had a longer growing season than the previous two years. In 1949 the growing season was approximately six weeks longer than in 1948 and five weeks longer than in 1947.

Although it seems apparent that a relationship exists between the first-year growth of sauger, *Stizostedion canadense canadense* (Smith) and the cycle of water-level changes in Norris Reservoir, further evidence of this association is required. The existence of other factors complicates the situation.

TABLE VI
ANNUAL MAXIMUM WATER ELEVATIONS FOR NORRIS RESERVOIR, TENNESSEE (1937-1949)*

Year	*Maximum Elevation (Nearest Foot)*
1937	1,031
1938	1,023
1939	1,013
1940	1,013
1941	996
1942	1,023
1943	1,022
1944	1,023
1945	1,018
1946	1,013
1947	995
1948	1,006
1949	1,017

* From Hydraulic Data Division, Tennessee Valley Authority.

SUMMARY

1. Various environmental factors were examined in relation to the first-year growth of sauger, *Stizostedion canadense canadense* (Smith), in Norris Reservoir, Tennessee.
2. No correlation was discernible between the length of the agricultural growing season and arbitrary fish growing season (first 60°F. temperature in spring (0.5 ft.) to the last 60° F. temperature in fall). The correlation between the length of the agricultural growing season and first-year sauger growth was not significant.
3. A significant positive correlation was obtained between the first-year growth of sauger and the annual number of days between water temperatures of 60° F. (0.5 ft.).
4. An inverse relationship was indicated between first-year growth of sauger and the time in days for water temperatures to increase from 50° F. to 60° F. in the spring.
5. A significant negative correlation was obtained between the first-year growth of sauger and the combined rainfall for February and March.
6. There was no apparent correlation between annual solar radiation and first-year growth of sauger. November was the only month in which the amount of solar radiation and sauger growth had a significant correlation coefficient.
7. No correlation existed between monthly and annual air temperatures and the first-year growth of sauger.
8. The relationship between water level fluctuations and the first-year growth of sauger indicated a possible cyclic trend, but additional data is required for this situation.

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