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by

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ABSTRACT

The effect of temperature on growth of young-of-the-year yellow perch was determined over an 8-week period at constant temperatures from 8° to 34° C. Absolute growth rates peaked at 28° C, but were not significantly less (P>0.05) over the range from 26° to 30° C. Deformities occurred at 32° C but at no lower temperatures, and all fish died within 7 days at 34° C. A suggested seasonal temperature cycle for yellow perch habitats is presented, based on the data from this experiment for the summer period of rapid growth and on data from previous studies for other life stages.

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SECTION I

CONCLUSIONS

Young-of-the-year yellow perch fed unrestricted rations and held at constant temperatures grew best at 26-30° C. The maximum growth rate occurred at 28° C. Growth rates at 20-24° C were significantly ($P \leq 0.05$) slower than those at 26-30° C. Little or no growth occurred at 8° C. At 32° C deformed individuals developed, and at 34° C all fish died within 7 days.

SECTION II

RECOMMENDATIONS

Temperatures should be from 26° to 30° C for rapid growth of young-of-the-year yellow perch fed unlimited rations. When food is limiting, the lower temperatures of this range will be more desirable, because of less efficient food conversion at higher temperatures. Maximum temperature for short periods should not exceed 32° C. These thermal recommendations are specific for the age group studied and should not be applied to other stages of development.

SECTION III

INTRODUCTION

This study was conducted to determine effects of temperature on growth of young-of-the-year (y-o-y) yellow perch, a life stage whose thermal requirements had not previously been delineated. Previous studies have provided data enabling evaluations of temperatures suitable for the well-being of yellow perch at most other life history stages (Hokanson and Kleiner, 1974; Jones et al., MS). Since growth tends to be a summation of an animal's response to its environment, it is considered a good measure of temperatures suitable for the species during the life stage tested. The information presented in this report fills a blank in our knowledge of the life cycle thermal requirements of the species. With the acquisition of these new data prediction of seasonal thermal limits for the welfare of the species is now possible, and a suggested seasonal cycle will be presented in the discussion section.

The yellow perch is of value as a sport and commercial fish of high table quality. It is also an important forage fish. Its value as a forage species has been described by Forney (1971, 1974), in studies of Oneida Lake, New York; Parsons (1971), in work on Lake Erie, and Swenson and Smith (1973), in work on Lake of the Woods, Minnesota. Maloney and Johnson (1955) even suggest a dependence of the year-class strength of walleye on the associated yellow perch year-class. This dependence results from similar habitat requirements and relative size relationships between the two species, making y-o-y yellow perch available as forage, both in space and size, to y-o-y walleyes.

SECTION IV

METHODS AND MATERIALS

The test system provided a continuous flow of water at approximately 350 ml/min to duplicate test chambers at a constant temperature (McCormick and Syrett, MS 1970). The glass test chambers were 20 by 15 cm by 60 cm long. The temperatures were monitored with a constant recording Honeywell multipoint telethermometer and were measured once daily in each chamber to the nearest 0.1° C with a standardized mercury thermometer. (Standardization was within ± 0.1° C of an ASTM certified calibration thermometer.) The mean temperatures reported are the pooled daily means of hourly means from both duplicates derived from the temperature recorder charts. Temperatures were maintained within ± 0.3° C (95% confidence limits) of the reported means. Temperature-control failures for brief periods resulted in temperatures beyond these limits, extremes (Table 1) usually only persisting for a few minutes. The failures were considered to have had no effect on the results, because of the long-term exposures to the reported mean temperatures, the narrow limits of the 95% C.I., and the absence of observable enduring effect after such temperature fluctuations.

Yellow perch y-o-y, average weight about 0.4 g, were collected fro. Park Lake, Carlton County, Minnesota, on July 25, 1973. The water temperature at the time of collection was 24° C. Before adjustment to test temperatures the fish were held 5 days at 21.0° C.

Untreated Lake Superior water was used throughout the experiment (total hardness 44-45 mg/l.; total alkalinity, of 41-43 mg/l.; pH 7.4-7.8).

Table 1. GROWTH AND DEATH RATES OF YOUNG-OF-THE-YEAR YELLOW PERCH HELD 8 WEEKS AT DIFFERENT CONSTANT TEMPERATURES. THE REPORTED INSTANTANEOUS RATES ARE THE MEANS OF TWO REPLICATES OVER FOUR SUBSAMPLING PERIODS

Mean temperature (°C) (range)	Growth (wet weight)			Death rate (%/day)
	Growth rate (%/day)	Initial mean size (g)	Terminal mean size (g)	
8 (7.0 - 9.5)	0.31	0.44	0.53	0.02
12 (10.3 - 13.1)	0.66	0.46	0.68	0.58
16 (15.5 - 16.8)	1.34	0.51	1.05	0.26
18 (16.9 - 18.6)	1.37	0.54	1.16	0.30
20 (17.9 - 21.0)	2.24	0.52	1.80	0.40
22 (19.9 - 31.1)	2.67	0.54	2.42	0.25
24 (22.0 - 31.0)	2.77	0.54	2.94	0.40
26 (24.8 - 32.1)	3.50	0.58	4.14	0.22
28 (17.9 - 28.3)	3.77[b]	0.74	4.71	0.04
30 (28.3 - 30.8)	3.47	0.53	3.74	0.02
32 (29.7 - 32.4)	2.85	0.56	2.76	0.06
34[a] (32.8 - 34.3)	—	0.51	—	55.62
Tukey's honestly significant difference, P=0.05 (%/day)	0.61			

[a]Means for this temperature exposure were for 6 days in replicate A and 5 days in replicate B. All fish died before sampling.

[b]Adjusted instantaneous growth rate for the replacement replicates described in materials and methods (3.13 %/day was the rate for the original replicates).

Dissolved oxygen concentrations were 6.0 ppm or greater, other chemical characteristics were as described by Biesinger and Christensen (1972). Lighting was by Duro-Test Vita-Lite fluorescent lamps with a photoperiod normal for July-September at the Duluth, Minnesota, latitude.

On July 27 and 28 fish were transferred to their respective test chambers in a stratified random manner, with one fish in each chamber before a second was added, until 72 fish were placed in each chamber. The order to temperature treatments was randomly assigned to remove position effects, although duplicates were adjacent.

At the time of distribution of the fish to the test chambers, all chambers were at about 20° C. Over the next 8 days all were gradually adjusted to test temperatures (Table 1). For those chambers that were to be at the greatest extremes from the initial acclimation temperature, adjustments were initially 2° or 5° C per day, but the last 5 days before test temperatures were reached adjustments were never greater than 1° C per day. This rate of adjustment insured acclimation to test temperatures (Brett, 1944).

During the thermal adjustment period all test fish were treated with formalin for removal of external parasites (Meyer, 1969) and with terramycin for control of bacterial disease. The parasite <u>Ichthyophthirius</u> sp. was not successfully eliminated, however, and repeated treatments were necessary throughout the study to control this organism. A malachite green-formalin mixture (Leteux and Meyer, 1972) at 30 ppm concentration, applied with flow-through techniques kept mortalities at a tolerable level throughout the experiment (Figure 1). Bacterial disease was only a problem at 28° C where the initial duplicates were both affected shortly before the end of the second 2-week growth period. Because this disease outbreak affected the feeding for a time and subsequent growth of survivors, two new replicates were started at 28° C. These fish were drawn from the original stock that had been kept at 20° C and fed the same diet during the intervening period.

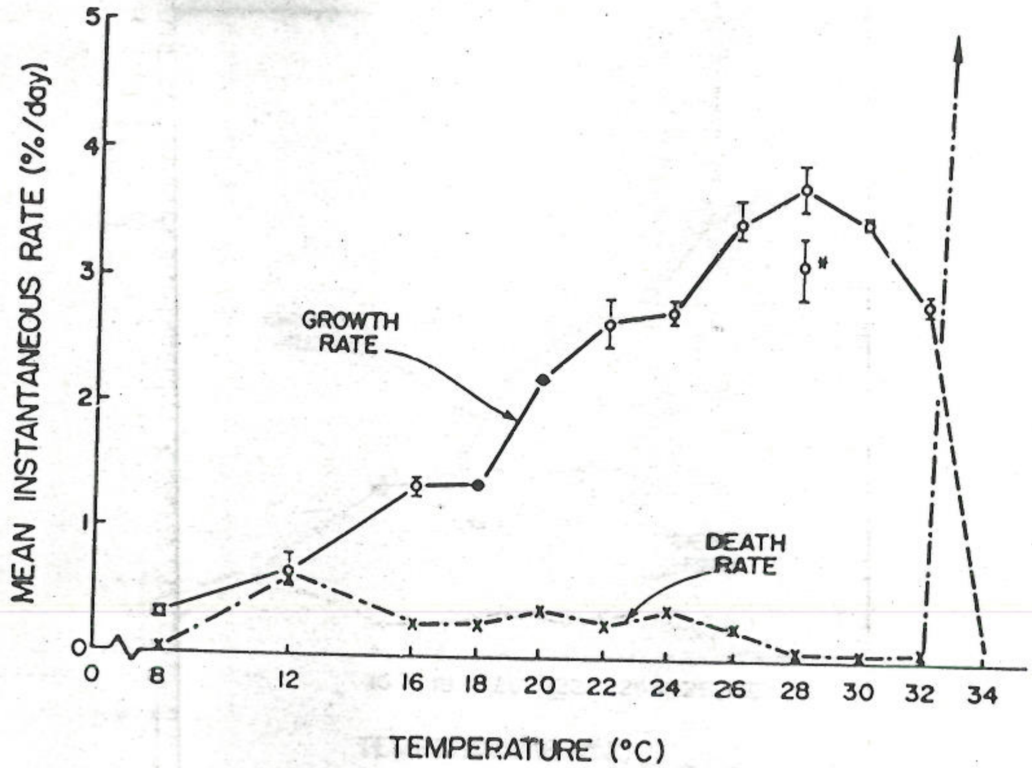

Figure 1. Instantaneous rates of growth and death (%/day) of young-of-the-year yellow perch reared at different constant temperatures with unlimited ration. The horizontal bars above and below each mean indicate the range between duplicates at each test temperature. Variability in growth rates between duplicates was so small at 16° and 18° C that the range bars appear as one. Growth rates of the original replicates at 28° C are marked by the asterisk.

Introduction to the test apparatus was at 25° C followed by tempering to 28° C at the rate of 1° C/day. The fish were then carried through 8 weeks of growth, 4 weeks later than the rest of the experimental units. The slightly greater initial size of fish in the replacement duplicates required adjustment of the resulting growth data to the starting size of the original 28° C test fish (Table 1).

Initially the fish were fed ad libitum with live newly hatched brine shrimp, Artemia salina. New ration was added early in the morning, late in the afternoon, and during the day when food density appeared low. On weekends the fish were fed only 2 or 3 times daily. Night feeding was not considered necessary as this species is principally a daytime feeder (Noble, 1973b). The initial diet of live brine shrimp, later supplemented several times daily with thawed frozen adult brine shrimp, was eventually supplemented with two additional components. The new diet regime consisted of the continuation of feeding live newly hatched brine shrimp, but added a one-to-one mixture of finely ground beef liver and thawed frozen adult brine shrimp with yeast. The new diet was fed with an eye-dropper. The fish were fed to repletion with this mixture at the beginning and end of the usual 8 hr work day and several times in between.

Rearing chambers were cleaned daily, and dead fish were counted and removed. Subsamples of 10 fish for weight measurements were removed from each test chamber at 2-week intervals. Exceptions to this procedure were the initial sampling consisting of 20 fish per duplicate to insure a better initial size base from which subsequent growth was calculated, and the 4-week sample at 24° duplicate B consisting of five fish, and the 4-week sample at 18° duplicate B consisting of nine fish, to allow full sample sizes of 10 fish/unit at later sampling dates. The two samples of less than 10 fish each were necessitated by mortalities beyond expectation. The fish were not fed on the morning of the sampling to insure that little, if any, weight of the sample would be due to ingested but unassimilated food (Noble, 1973a).

Fish were preserved before weighing in formalin-picric-trichloro-acetic solution (Davenport, 1960). They were blotted on paper toweling and weighed, and the mean weight per fish was reported to the nearest hundredth of a gram. Subsampling at 2-week intervals provided specimens for weight changes at progressive time intervals, as well as population-density adjustments as the indiviiuals increased in size.

Instantaneous rate of growth (wet weight) and mortality were calculated for each sampling interval on a percentage per day basis (Ricker, 1958). The weighted mean rates for the four sampling periods were used as treatment effects in the analysis (Table 1). One-way analysis of variance and Tukey's honestly significant difference (Steel and Torrie, 1960) were used to detect the effect of temperature on the rate of growth great enough to be considered significant at the 95% level. Mortality data during the first 7 days at 32° and 34° C were used to locate the temperature range incorporating the 7-day TL50 value.

SECTION V

RESULTS

Instantaneous growth rates of y-o-y yellow perch reared on unrestricted rations at constant temperatures were highest, and statistically equal, over the temperature range 26° to 30° C ($P \geq 0.05$). The maximum rate of 3.77 %/day occurred at 28° C (Table 1, Figure 1), and at 26° and 30° C rates were 3.50 %/day and 3.47 %/day, respectively. Temperatures from 20° to 24° C produced growth rates of 2.24 and 2.77 %/day, which were statistically less ($P < 0.05$) than at 26° C.

The growth rate of 2.85 %/day at 32° C was not a great reduction from the maximum rate, but of more significance, was the production at this temperature of a population of fish with greater than 85% of the individuals with marked curvatures of the spine. These deformities were not found at lower temperatures. At 34° C all fish died before the end of the first 7 days of exposure.

The overall mortality was complicated by the deaths that were not temperature dependent. Some deaths were at least in part due to the chronic infestation of Ichthyophthirius sp. Mortality was 0.02 %/day at 8° C, rose to an unsteady plateau of, 0.22-0.58 %/day over the temperature range from 12° to 26° C, and then declined again at 28-32° C to 0.02-0.06 %/day.

During the first 7 days of exposure to 32° C and 34° C, no deaths occurred among the 32° C exposed fish, but all fish died at 34° C. The 7-day TL50 is thus considered to lie between these two temperatures. Without mid-range data points it is not possible to estimate whether the TL50 lies on the higher or lower extreme of this range.

SECTION VI

DISCUSSION

Weekend feeding was not as frequent as during the rest of the week -- only two to three times daily. This shortcoming was believed to have been insignificant as it was at least partially compensated for by an increased food consumption at the first of the following week (McCay et al., 1929; Moore, 1941). There is, however, some question that compensation is complete (Shelbourn et al., 1973).

We believe that the loss of the original replicates at 28° C was well corrected by the incorporation of the two replacement replicates at that temperature. Since growth rates tend to be more rapid among smaller fish (Pessah and Powles, 1974), the rate determined in the replacement replicates would probably have been higher had the fish been started at the same size as the originals. In either case 28° C would have produced the maximum rate of growth among the temperatures tested, a temperature close to the 27° C to which yellow perch thermoregulated in a thermal discharge in Lake Monona, Wisconsin, where food was more abundant than in unheated areas (Neill, 1971).

The absence of exposure temperatures between 32° and 34° C prevented the establishment of a precise 7-day TL50 temperature, but our data support the value of 32.3° found by Hart (1952).

Growth rate alone may not be an adequate evaluation of the responses of fish to exposures to various temperatures over extended time. The growth rate at 32° C was only slightly outside the statistically homogeneous set of rapid growth rates from 26° to 30° C, but, because of the great incidence of curvatures of the spine among these fish, 32° C can be considered with confidence as unsuitable for the well-being of yellow perch for prolonged unavoidable exposure. In addition, the effects of temperature on production must be considered. Since production is a function of both growth rate and mean biomass (Warren, 1971) nearly equal rates of growth, such as occurred in this experiment at 20°, 24°, and 32° C, may not promote equal production if biomass is altered by temperature. Biomass can be expected to be reduced at higher temperatures as it is known that the efficiency of conversion of available food is reduced as temperature increases (Gray, 1929; McCormick, 1960). It is also known that as food becomes more limiting maximum growth takes place at progressively lower temperatures (Brett et al., 1969). Consequently, any value for production based on data from this experiment, where food was not limiting, must be considered maximum for any temperature considered. Thus, the most favorable temperatures for this species during the juvenile growth period cannot be expected to be higher than those reported here and can be expected to be lower when food is limited or some other stress is brought to bear.

Previous studies of the yellow perch have provided information on temperatures required for most other life stages. Overwinter temperatures of 4-6° C permit maturation and successful spring spawning, but 8° C results in reduced success and 10° C practically none (Jones et al., MS). They also reported that when perch have been provided with an appropriate overwinter temperature regimen spawning with greatest success occurs at 11.3° C with only slight reductions between 7.5° and 12.7° C. Hokanson and Kleiner (1974) reported that embryos exposed to constant temperatures before their first cleavage had their greatest success in hatching at 16° C, with an optimum range for hatching from 10.1° through 18.2° C. Embryos exposed after neural keel formation had broader thermal tolerance limits; maximum hatching took place at 19.9° C, and the optimum range extended from 13.1° through 22.1° C. They found even greater hatching success when temperatures were allowed to rise during the incubation period at rates of 0.5° C/day or 1.0° C/day from starting temperatures of 5-10° to as high as 24.3° C at hatching. For swim-up larvae they report 13.1-18.2° C as optimum.

Adults coexist in time with juveniles, but are expected to require temperatures a few degrees lower, which may explain their usual presence a little farther offshore in deeper, cooler water. Preferred temperatures for juveniles are reported to be between 20° and 24° C (McCauley and Read, 1973; Ferguson, 1958); adults studied by these authors preferred temperatures a few degrees lower, between 18° and 21° C. To accommodate the requirements of two coexisting life stages, y-o-y and adults, the inshore zone would be managed for y-o-y and the offshore zone of cooler water for older age groups.

The fall period is one of transition to overwintering temperatures, apparently only requiring a rate of temperature reduction not to exceed the lethal limits at successively lower acclimation and to initiate gonadal maturation preparatory to spring spawning (Turner, 1919; LeCren, 1951). Brett (1944) suggests a rate of decline not to exceed 1° C/day as one with which thermal acclimation of fish can keep pace.

With the addition of the data presented in this report a complete, suitable temperature regime can now be suggested for the yellow perch at each season as it proceeds from one life stage to the next. Figure 2 is such a suggested seasonal temperature regime. Exact dates are omitted as the time of the various life stages may vary a week or more with latitudinal distribution (consult local authorities for dates). The temperature limits for the well-being of this species as it seasonally progresses from one life stage to the next are also shown in Figure 2. A close correlation is apparent between the seasonally related life stages and the natural temperatures expected for those seasons where yellow perch are found which is probably evolutionarily derived. This relationship, emphasizes the need to retain such seasonal temperature cycles in the habitat of the yellow perch if it and its associated dependent species are to prosper.

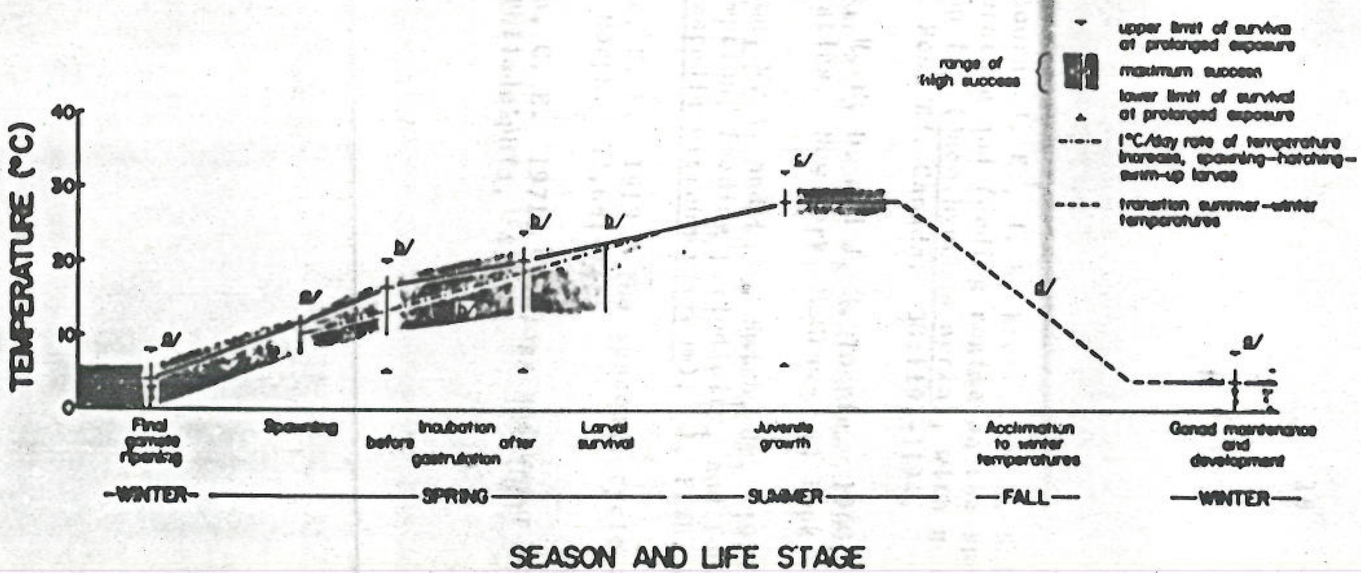

Figure 2. A temperature regime suitable for yellow perch at each season of the year and the critical life stages extant during those seasons. Footnotes indicate sources of data used in establishing the various limits.

a Jones, B. R. et al. (personal communication publication in preparation).

b Hokanson, K. E. F., and C. F. Kleiner (1974).

c McCormick, J. H. (this report).

d Brett, J. R. (1944).

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