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The Effect of Temperature on the Growth of Juvenile Lake Sturgeon, *Acipenser fulvescens*

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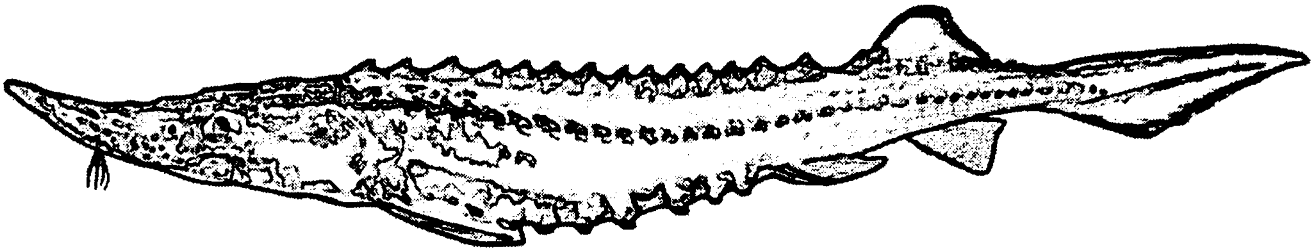

DNR

STATE OF MICHIGAN
DEPARTMENT OF NATURAL RESOURCES

The Effect of Temperature on the Growth of Juvenile Lake Sturgeon, *Acipenser fulvescens*

by

Kevin E. Wehrly

A thesis submitted
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Abstract

I measured growth of lake sturgeon at maximum ration over 28 days at 7, 10.5, 15, 19 and 23 °C, and compared these results with published data for other fish species. Fish were fed to excess on dead chironomid larvae twice a day. Growth rates increased linearly with temperature from 0.71 % BW/d at 7 °C to 1.52 % BW/d at 23 °C based on wet weight, from 0.21 % BW/d at 7 °C to 1.02 % BW/d at 23 °C based on dry weight, and from 3.25 kJ/g• d at 7 °C to 16.37 kJ/g• d at 23 °C in terms of energy . Mortality also increased linearly with temperature from 18 % at 7 °C to 45 % at 23 °C. High mortality at 23 °C suggests that this temperature is close to the upper incipient tolerance level of these fish. Sturgeon growth rates were similar to those reported for salmonids. Slow growth exhibited by sturgeon in the wild is probably due to limited food availability.

Introduction

The lake sturgeon *Acipenser fulvescens*, is one of seven species of sturgeon of North America, indigenous to the Mississippi, Great Lakes and Hudson Bay drainages (Scott and Crossman 1973). It is an unusual freshwater fish because of its longevity, late maturity and large size (Probst and Cooper 1954). Sturgeon reach sexual maturity at ages from 20 to 30 years and may live for over 100 years. Like other members of the family Acipenseridae, lake sturgeon exhibit relatively slow growth rates.

The unique life history of the lake sturgeon is rivaled only by the history of their decline in the Great Lakes Region. Prior to 1830, sturgeon populations in the Great Lakes were estimated in the tens of millions of kilograms (Tody 1974). Currently, however, they are considered threatened by the American Fisheries Society (Deacon et al. 1979) and are classified as rare by the United States Department of the Interior (Anonymous 1966). These classifications result from over fishing, slow growth, late maturity and the resultant small population sizes of the species. Only a few exploitable lake sturgeon stocks exist today and controlled harvests are permitted exclusively in sport fisheries. The total catch, however, is far below demand and poaching is believed to be substantial (Baker 1980).

Because of conflicts between demands for fishing and conservation, programs have been established to increase sturgeon populations and enhance the fishery. These efforts have resulted in the successful culture of young sturgeon from eggs for planting (Anderson 1984; Ceskleba et al. 1985), and studies evaluating habitat preferences and behavior to improve stocking practices and to facilitate habitat protection (Hay-Chmielewski 1987; Kempinger 1988; Thuemler 1988).

One of the major factors contributing to the loss of sturgeon populations is their slow growth rate and late maturity (Probst and Cooper 1954). These may result from environmental factors reducing food availability, such as low food productivity or high search costs, or an intrinsic, genetically determined growth pattern. The latter occurs in many species of animals that have evolved life histories with characteristics typical of sturgeon, and is usually associated with stable environments or dispersion and unpredictability of food in time and/or space (Ware 1982; Pough 1983; Roff 1984). Thus sturgeon may have evolved a life-history pattern based on low energy use.

The objective of this study was to determine if sturgeon are food limited or have a lifestyle emphasizing low energy use by measuring the effect of temperature on growth of juvenile sturgeon fed excess ration, and comparing these data to published data on growth of other fish species.

Methods

Lake sturgeon were obtained from the Wolf Lake State Fish Hatchery in Michigan, where they were raised from eggs collected from the Menominee River by the Wisconsin Department of Natural Resources. Fish were held in the laboratory at 15 °C and fed *ad libitum* on dead chironomid larvae for one month prior to experiments. Sturgeon were housed in 110 L (bottom area 0.41 m^2) aerated tanks with continuous water replacement. Studies were conducted under constant illumination to eliminate possible effects of photoperiod on growth.

To determine the effects of temperature on growth, I used a single-batch multi-time method as described by Brett et al. (1969). To begin the experiment, 258 sturgeon with a mean initial weight of 16.25 g were individually weighed and randomly assigned into 5 tanks. Temperatures in these tanks were adjusted over 7 days to test temperatures of 7, 10.5, 15, 19 and 23 °C. The highest temperature (23 °C) was chosen following preliminary studies which demonstrated substantial mortalities within 5 days at 25 °C. After tanks reached test temperatures, fish were held for a 14-day acclimation period. All fish were then anesthetized and weighed. Fish were reweighed after 14 and 28 days.

Fish were fed an excess ration of chironomid larvae twice per day. Some fish died in every treatment. These were removed from the tanks and their weights recorded. Growth (% BW/d), based on wet weight, was calculated for each treatment as the difference between average initial and final wet weight divided by the mean body weight and by the number of days.

Subsamples of 5 fish per treatment were removed at the beginning, middle and end of the experiment to determine changes in body composition. These samples were dried at 80 °C, homogenized and combusted in a Phillipson microbomb calorimeter to determine energy content. Initial and final dry weights for fish in each treatment were estimated by multiplying the average % dry weight for the subsample of fish by the individual wet weights within each treatment. Growth (% BW/d) based on dry weight was calculated for each treatment as the difference between initial and final dry weight divided by the mean body weight and by the number of days. Initial and final energy content and total growth (kJ/ grams• day) for fish in each treatment were calculated similarly, substituting energy content for % dry weight.

Differences in mean weight and body composition among groups were determined using analysis of variance. Size depensation occurred and to meet assumptions of normality, wet and dry weights were analyzed using log-transformed data. Changes in body composition at each sampling date were determined using Student's t-test. Relationships between temperature and growth were analyzed with regression analysis. In all statistical tests, alpha was set at 0.05. Statistical analyses were performed using SYSTAT (Wilkinson 1990).

Results

Sturgeon at all temperatures gained weight during the 28-day test period, and fish at higher temperatures tended to grow faster (Figure 1). Mortality also increased with increasing temperature (Figure 2). The size range of dying fish did not differ from survivors. Therefore, growth rates based on mean weights at sampling periods were not biased and did not need to be corrected.

Coefficients of variation at the beginning of the experiment were large (mean = 38%), indicating that fish size varied considerably in the treatments. This variation did not change over the 28 days except at the highest temperature at which variation in fish size increased from 40 to 57 % by day 28.

Growth rates based on wet weight ranged from 0.71 % BW/d at 7 °C to 1.52 % BW/d at 23 °C. There was a general increase in growth rate with increasing temperature and these data were fitted by a linear relationship that explained 80 % of the variance (Figure 3A).

Water content did not vary significantly among treatments at the beginning or end of the experiment (ANOVA; $p = 0.466$ and 0.099, respectively). Water content did increase significantly over the 28-day experiment (from 84.3 to 86.4 %; Student's t-test; $p < 0.001$). Resulting growth rates based on dry weight ranged from 0.21 % BW/d at 7 °C to 1.02 % BW/d at 23 °C, and generally increased with temperature (Figure 3B).

Initial and final energy densities also did not vary significantly among treatments (ANOVA; $p = 0.083$ and 0.122, respectively), and pooled initial and final energy densities were not significantly different (Student's t-test; $p = 0.287$). Therefore, rates of growth in energy terms show similar trends to wet weight.

Discussion

Growth rates of lake sturgeon fed excess ration, whether measured in terms of wet weight, dry weight or energy content, increased with temperature. This pattern is similar to that found for three-spined sticklebacks *Gasterosteus aculeatus* (Allan and Wooton 1982), but differs from the dome-shape found for salmonids (Brett 1979, Elliot 1975, McCormick 1972).

Allan and Wootton (1982) suggest continuously increasing growth with temperature, as found for sturgeon, occurs when experimental temperatures span too small a proportion of the range between lower and upper incipient lethal temperatures. However, my preliminary work resulted in mortality of 100 % in 5 days at 25 °C, and the present study resulted in 45 % mortality in 28 days at 23 °C. Therefore, the 23 °C treatment must be close to the upper incipient lethal temperature for these fish. This suggests that sturgeon growth increases throughout their temperature tolerance range.

However, the coefficient of variation for body size increased with time at 23 °C, associated with rapid growth of a small number of fish (Figure 4). Therefore, increased average growth at higher temperatures was the result of greater growth by a few fish. Recalculation of growth after removal of the 6 largest individuals at the beginning and end of the experiment resulted in growth rates of 1.00 % wet BW/d and 0.55 % dry BW/d, similar to rates at 10 and 15 °C. Therefore, reduced growth occurred at higher temperatures for the majority of sturgeon. Hatchery selection for larger individuals cultured at higher temperatures could isolate individuals for planting in warmer lakes and rivers with a greater probability of enhancing recovery of populations.

Growth rates in this study were of the same order, but somewhat lower than growth rates found in other studies on this species. Diana et al. (1994) report growth rates of 2.59 % BW/d for juvenile fish fed *ad libitum* twice per day at 17.5 °C, and 1.82 % BW/d for fish fed *ad libitum* once per day. The lower growth rates found in this study may relate to differences in food quality. Diana et al. (1994) used live worms (*Nadis*) with an energy content 40 % greater than the dead chironomid larvae used in this study.

Therefore, if sturgeon fed to satiation in both sets of experiments, those in the present experiment would be expected to grow at lower rates because of differences in energy density of food. These results also suggest that hatchery-reared sturgeon may achieve higher growth rates and attain a larger size at planting if maintained on live diets. Live foods, however, are expensive and the cost of maintaining fish on live foods versus any increase in survivorship remains to be tested.

The hypothesis that the lake sturgeon is an energy conservor, with lower growth rates than other fish, is not supported by the data. Equations for specific-growth developed by Brett and Shelbourn (1975) and Elliot (1975) predict maximum growth of sockeye salmon *Oncorhynchus nerka* of 1.32 % BW/d at 15 °C, and 1.10 % BW/d at 12.8 °C for brown trout *Salmo trutta*. A comparison of these data with growth rates obtained in this study and those reported in the literature (Table 3) indicate that sturgeon have the capacity for rapid growth as juveniles. Rapid growth of young is typical among fish and may be important in minimizing mortality risks during early life history stages (Werner and Gilliam 1984).

This study has implications for the management of lake sturgeon. The relationship between mortality and temperature suggests that temperature may be an important factor influencing survivorship of young of year (YOY) sturgeon. The temperature range over which growth was measured falls within the range of temperatures experienced by adult sturgeon in inland lakes (Hay-Chmielewski 1987). More importantly, YOY sturgeon migrate to lake habitats 9 to 10 days after hatching (Kempinger 1988) and may therefore be subjected to temperatures at or near 23 °C during their third (July) and fourth (August) month (Hay-Chmielewski, Black Lake, Michigan unpublished temperature data). Hatchery-reared sturgeon are usually stocked in June. Thus, the temperatures experienced during July and August may present a potential bottleneck for YOY wild and planted sturgeon. Currently, little information is available on survivorship of lake sturgeon, and additional studies are required to evaluate the role of temperature. Nevertheless, attempts to expand the range of lake sturgeon (i.e. stocking in inland lakes previously uninhabited by sturgeon) should include temperature as a selection criteria when evaluating potential lakes for stocking.

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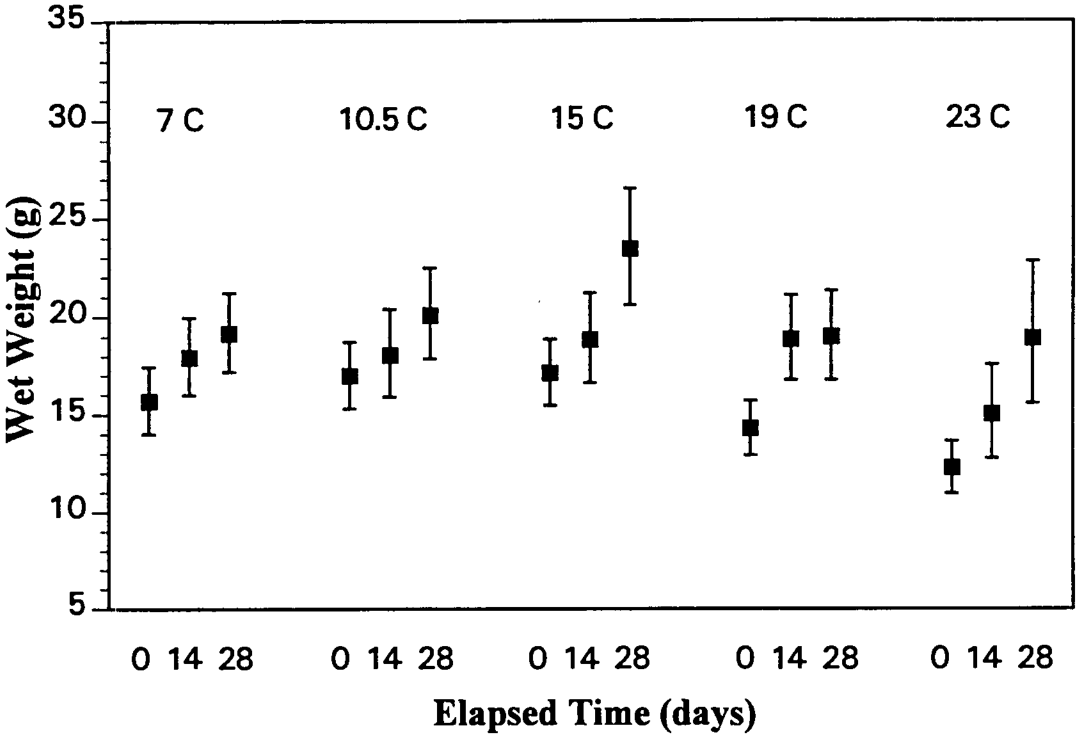

Figure 1. Changes in the average body weight of lake sturgeon at each temperature over 28 days. Vertical bars are ± 2 standard errors.

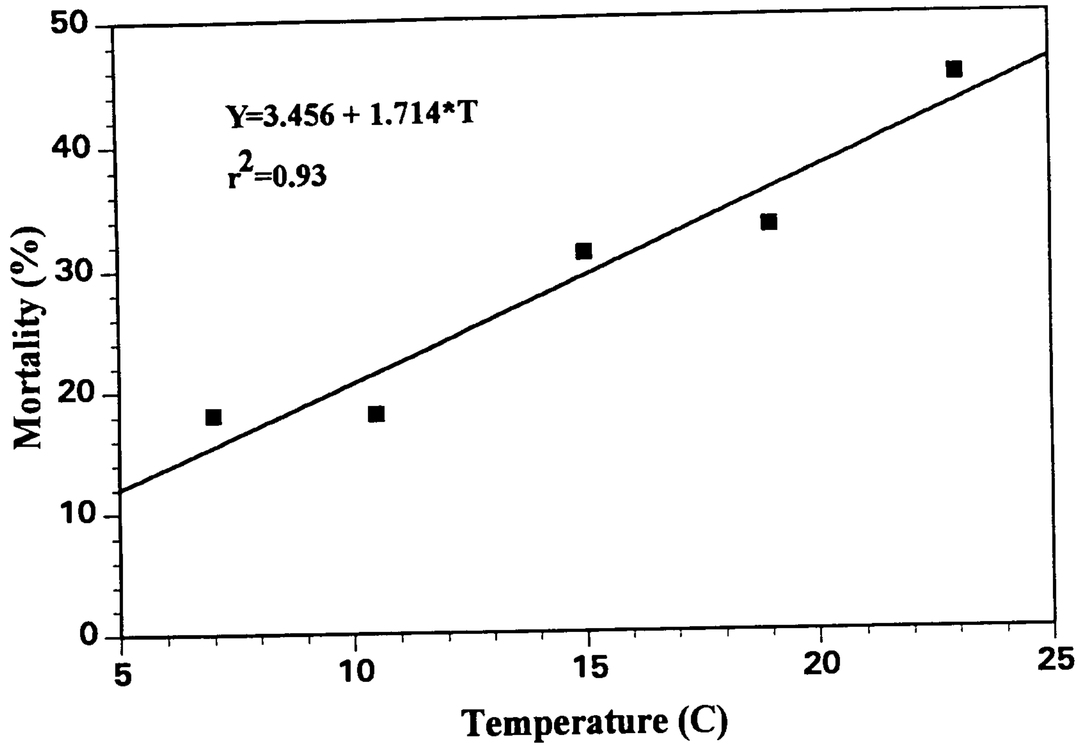

Figure 2. The relationship between temperature and mortality of lake sturgeon over 28 days.

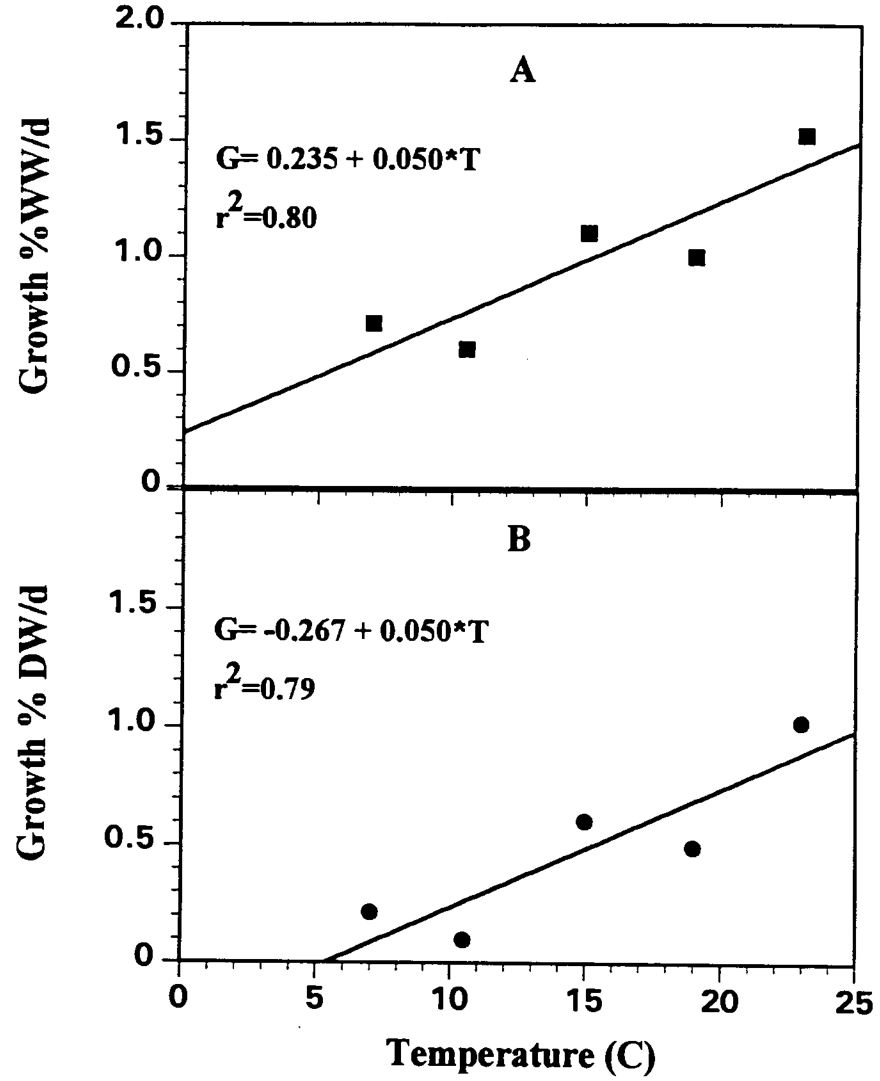

Figure 3. The relationship between temperature and growth rate based on wet weight (A) and dry weight (B).

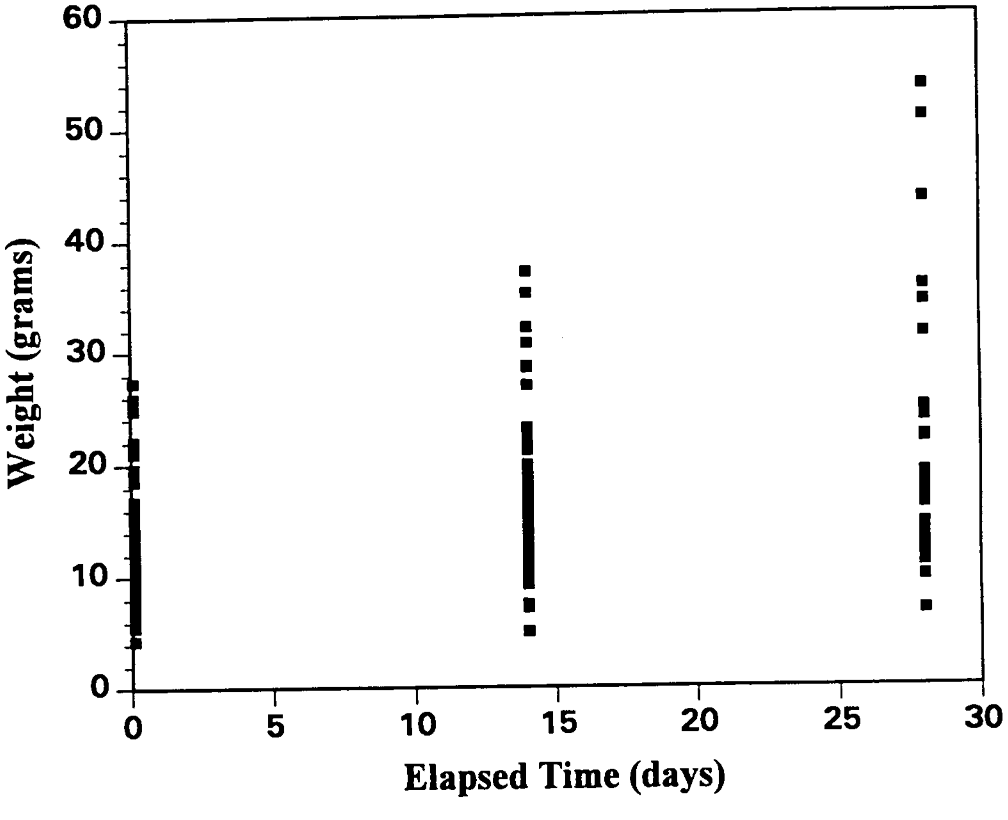

Figure 4. Changes in the size composition over time for lake sturgeon in the 23 ˚C treatment.

Table 1. Data derived from mass specific growth equations for sockeye salmon and brown trout and growth rates of lake sturgeon. Equation for sockeye salmon: $LnG = 4.47 + -0.42(LnW)$. Equation for brown trout: $G = 100(-0.0100 + 0.0029)W^{\wedge} -0.3250$. G is growth rate (%BW/d), and W is initial weight.

Species	Temperature (°C)	Growth (%BW/d)	Reference
sockeye salmon	15	1.32	Brett and Shelbourn 1975
brown trout	12.8	1.10	Elliot 1975
lake sturgeon	15	1.13	This study
lake sturgeon	17.5	2.59	Diana et al. 1994