Michigan
DNR

STATE OF MICHIGAN
DEPARTMENT OF NATURAL RESOURCES

Number 2003-1

May 16, 2003

Experiments on Tolerance of Incubating Walleye Eggs to Temperature Fluctuations

James C. Schneider
James Copeland
and
Martha Wolgamood

www.michigan.gov/dnr/

FISHERIES DIVISION
TECHNICAL REPORT

MICHIGAN DEPARTMENT OF NATURAL RESOURCES
FISHERIES DIVISION

Fisheries Technical Report 2003-1
May 16, 2003

Experiments on Tolerance of Incubating Walleye Eggs to Temperature Fluctuations

James C. Schneider
James Copeland
and
Martha Wolgamood

Michigan DNR
Printed under authority of Michigan Department of Natural Resources
Total number of copies printed 200 — Total cost $181.86 — Cost per copy $0.91

Michigan Department of Natural Resources
Fisheries Technical Report 2003-1, 2003

Experiments on Tolerance of Incubating Walleye Eggs to Temperature Fluctuations[a]

James C. Schneider[b]

Institute for Fisheries Research
212 Museums Annex Building
Ann Arbor, Michigan 48109-1084

James Copeland[b] **and Martha Wolgamood**

Wolf Lake State Fish Hatchery
34270 C.R. 652
Mattawan, Michigan 49071

Abstract.–Eggs of walleyes *Stizostedion vitreum* incubating under hatchery conditions were subjected to one of five temperature fluctuations compared to normal rearing temperatures: -8.8ºC on days 3-6, -9.3ºC on days 7-10, +13.6ºC on days 7-8, +20.2ºC on days 7-8, or -9.4ºC followed by +21.1ºC on days 7-10. The maximum rate of temperature change was 2.5ºC/hr. We found that eye-up rates remained at approximately 70% for all control and test lots. Swim-up rates of approximately 90% for the control and the first three temperature variations were reduced to 42% and 13.6% for the last two temperature variations (>20ºC). We conclude that temperature fluctuations great enough to directly affect incubating walleye eggs are unlikely to occur in hatcheries or on natural spawning grounds.

The spawning success and subsequent recruitment of young walleye *Stizostedion vitreum* to natural populations is irregular throughout North America (reviewed by Koonce et al. 1977). Walleyes initiate spawning in early spring when water temperatures rise to approximately 8ºC and may continue spawning for 1-3 weeks (Colby et al. 1979). The length of the incubation period is temperature dependent and typically lasts 2-3 weeks at prevailing cool temperatures (Colby et al. 1979). Many small, unprotected eggs are deposited and their hatching success tends to be low. A hatching rate of only 60-70% is normal for the State of Michigan production facility at Mattawan (J. Copeland), and a hatching rate of 51% was reported from an Illinois hatchery (Heidinger et al. 1997). Hatching rates in the wild can be much lower (Johnson 1961). High egg mortality may occur within the first 6 h due to poor viability or lack of fertilization (Heidinger et al. 1997).

Survival of eggs and fry in the wild has been linked to weather conditions and availability of

[a] Contents of this report were published in the North American Journal of Aquaculture 64:75-78, as "Tolerance of incubating walleye eggs to temperature fluctuation."
[b] Retired

food for fry (Johnson 1961; Hokanson 1977; Koonce et al. 1977; Colby et al. 1979). Generally, steadily rising temperatures and calm lake conditions during incubation favor good hatching success and strong year classes. Fluctuating temperatures during incubation are sometimes associated with weak year-classes. In Jewett Lake, Michigan, year-class failures were more likely when daily air temperature fluctuations during the egg incubation period exceeded 27.8ºC, which was approximately equivalent to a 7ºC daily fluctuation in water temperature (Schneider 1995). The water temperature of Jewett Lake varies more than that of most lakes in the region on sunny and calm days because it is very small, shallow, and protected from the wind, and has dark substrate.

In laboratory studies of eggs and fry, temperature ranges for optimum survival have been fairly wide: 6-12ºC during fertilization, 9-15ºC during egg incubation, and 15-21ºC from hatching to yolk sac absorption (Koenst and Smith 1976). Four additional reports (based on controlled experiments) provided some additional information on the tolerance of walleye eggs to temperature. Hokanson (1977) reported embryo lower and upper TL50s (the temperatures lethal to 50% of the test animals) to be 6.0ºC and 19.1ºC respectively when rearing occurred under constant temperatures. Allbaugh and Manz (1964) reported that a change in temperature during organogenesis from 11.7 to 30.6ºC and back to 11.7ºC (±19ºC) over 2 h caused neither “excessive mortality nor any immediate adverse effect” in seven jars of eggs and only a 50% mortality in the eighth jar. Zitzow (1991) successfully incubated walleye eggs by maintaining them at 12.2-15ºC for the first 3 d, reducing the temperature to 5.6-7.2ºC over 8 h and holding it constant for 24 d, increasing it to about 18.3ºC over 8 h, and completing incubation at 16.7-20.5ºC. Thus, a 7ºC decline and a 12ºC increase, each over 8 h, were not harmful. Malison et al. (2001), during attempts to create polyploids, reported some mortality of walleye eggs 1-5 min old when temperature was abruptly increased from 11ºC to 29-32ºC. These results suggest walleye eggs are quite tolerant of temperature changes as great as ±19ºC. For fry in the yolk sac stage, Clapp et al. (1997) recommended that stocking not occur when receiving water was either above 20ºC or more than 6ºC higher than transport water. However, Clapp et al. (1997) found that fry tolerated temperature changes of 1.5ºC/min, a relatively high rate compared to changes likely to occur in natural spawning areas.

The purpose of the following experiments were to evaluate walleye development rates to the eye-up and swim-up stages after exposure to three levels of temperature fluctuations under controlled hatchery conditions. Such information could be used to evaluate limitations on the spawning success of wild walleye populations as well as potential constraints on hatchery operations.

Methods

Experiments were conducted at the Wolf Lake State Fish Hatchery in Mattawan, Michigan, the state’s primary walleye culture facility. Standard egg collection and hatchery practices were followed except for prescribed temperature fluctuations. Adult walleyes were captured from the Muskegon River by electrofishing on April 8, 1996, and held in a pond until ripe; then their eggs were stripped and fertilized at 6.8ºC. Bentonite was added to prevent egg clumping. Eggs were transported to the hatchery where temperature was maintained constant at 10-11ºC by groundwater. Well-mixed samples of eggs were distributed among 14 incubation jars at a density of 1 L of eggs (approximately 139,600 eggs) per jar. All jars were treated with formalin for fungus control for the first 8 d of incubation at a dosage of 1:600 for 15 min. No disease problems were encountered during culture and dead eggs were not culled until after the eye-up stage.

Of the 14 jars, 4 were controls incubated at normal temperatures (10.5ºC, raised to 15ºC near hatching) and 10 received one of five experimental treatments. Experimental jars were gradually subjected to either two types of cold stress (-8.8ºC on days 3-6 or -9.3ºC on days 7-10), two types of heat stress (+13.6ºC or +20.2ºC on days 7-10), or a combination cold and heat stress (-9.4ºC followed by +21.1ºC over days 7-10), as described in Table 1. Eggs in the first four treatments were returned to the normal temperature sequence; eggs in the fifth group were hatched at 22.2ºC. The maximum rate of temperature change was 2.5ºC/hr. Egg survival rates were measured at eye-up, which occurred about 7 d after fertilization. After that, survivors in replicate jars were combined, except for treatment 5. Survival rates were determined again at swim-up, which occurred about 3 d after hatching, and the number of fry per cubic centimeter was determined. Chi-square tests and decomposition methods given by Snedecor and Cochran (1989:197) were used to evaluate statistical significance ($P < 0.05$).

Results

Temperature treatments had no effect on eye-up rate but a significant effect on swim-up rate (Table 2). Eggs in all control and experimental jars eyed-up at rates of 67-70%, the same as eggs incubated in hatching jars for normal production elsewhere in the hatchery. Swim-up rates were significantly different across all groups ($\chi^2 = 93.1$, df = 4). Swim-up rates were similar (90-94%) for control eggs and those exposed to thermal fluctuations as great as 13.6ºC. However, swim-up rates were 42% for stresses of +20.2ºC and 11-16% for stresses of ±21.2ºC. Those two extreme treatments contributed nearly all of the significance to the chi-square test. We also observed higher rates of deformity in the high temperature-stressed groups as well as a tendency for there to be slightly fewer fry per cubic centimeter (Table 2).

Discussion

Developing walleye eggs exhibit a remarkable tolerance to temperature fluctuations. No effect in swim-up survival was evident at a heat stress of +13.6ºC, and some swim-up fry were produced at a combined cold and heat stress of ±21.2ºC. This finding supports prior hatchery observations in which temperature fluctuations as great as ±19ºC had only small effects on incubation success (Allbaugh and Manz 1964; Zitzow 1991). Egg hatching success in our experiment was better than anticipated from Hokanson's (1977) report that constant incubation temperatures of less than 6.0ºC or more than 19.1ºC would be detrimental; however, those values were only briefly exceeded during our experiment. In experimental attempts to induce triploidy, walleye eggs were also resistant to very abrupt heat shocks applied 1-5 min after fertilization and lasting 10-25 min (Malison et al. 2001). Survival was moderately reduced by an increase from 11ºC to 28ºC and substantially reduced by increases from 11ºC to 30-32ºC.

These results have implications for cultural operations as well as for the walleye recruitment process in nature. In hatcheries, temperature need not be rigidly controlled. In nature, walleye eggs are sufficiently tolerant that temperature fluctuations are not likely to cause direct mortality. This is a fitting adaptation for a species that spawns in early spring. Fluctuations in air temperature and solar heating can be considerable in early spring, but fluctuations in water temperature are buffered by the cool water mass. On walleye spawning grounds in lakes and rivers, temperature fluctuations high enough to reduce hatching success (between 14ºC and 19ºC) are very unlikely to occur.

However, six other temperature-related factors may affect walleye recruitment. First, stressed eggs may produce stressed fry that will not perform well after swim-up, the last stage we monitored. In other species of fish, there is evidence that reduced fitness may appear at a later stage (von Westernhagen 1988). Second, the optimum of 15-21ºC for fry (Keast and Smith 1976) may not occur at the required time in relatively cold habitats such as ground water-fed rivers or very large northern lakes. Third, fry may not adapt well from endogenous to exogenous feeding, a vulnerable stage that is indirectly temperature dependent because it requires a coincidental pulse in zooplankton of the proper density, species, and size (Li and Mathias 1982; Johnston and Mathias 1993, 1994; Mayer and Wahl 1997; Jonas and Wahl 1998). Fourth, high temperatures can stimulate the growth of filamentous algae and fungi that can smother eggs (Colby et al. 1979). Fifth, cool temperatures prolong the incubation period and increase the risk of losses to storms, predation, or disease (Colby et al. 1979). These factors seem more likely to affect recruitment than direct lethal effects of temperature on incubation success.

Acknowledgements

The study was supported by the Fisheries Division, Michigan Department of Natural Resources. Staff at the Comstock Park Fisheries Office, Michigan, assisted with the collection of adults and eggs. Charles Pecor and two anonymous reviewers provided helpful comments.

Table 1.–Control and experimental treatments applied to incubating walleye eggs. The control treatment was applied to four incubation jars, the other treatments to two jars each; each jar contained approximately 139,6000 eggs.

Treatment	Description of temperature changes
Control	Held at 10-11ºC on days 1-15; on day 16 raised to 15ºC and held until hatched.
Cold: -8.8ºC on day 3	On day 3 lowered to 1.6ºC in 5 h and held; on day 6 returned to 10.5ºC and held; on day 18 raised to 15ºC and held until hatched.
Cold: -9.3ºC on day 7	On day 7 lowered to 1.2ºC over 8 h and held; on day 10 returned to 10.6ºC and held; on day 18 raised to 15ºC and held until hatched.
Heat: +13.6ºC on day7	On day 7 raised to 24.2ºC over 12 h and returned to 10.5ºC over 8 h and held; on day 15 raised to 15ºC and held until hatched.
Heat: +20.2ºC on day 7	On day 7 raised to 30.7ºC over 12 h and returned to 10.5ºC over 8 h and held; on day 15 raised to 15ºC and held until hatched.
Cold and heat: ±21.1ºC on days 7-10	On day 7 lowered to 1.1ºC over 14 h; on day 9 raised to 22.2C over 2 d and held until hatched.

Table 2.–Days to hatch, percent eye-up and swim-up, and number of fry/cm^3 for walleye eggs subjected to cold and heat shocks during incubation. The control treatment was applied to four incubation jars, the other treatments to two jars each. Mean values for the control were as follows: hatch = 16 d; eye-up = 69.8%; swim-up =91.9%; and fry/cm^3 = 200.

Treatment	Temperature sequence (ºC)	Hatch (d)	Eye-up (%)	Swim-up (%)	Fry/cm^3
Control	10-11, 15	16	72.0		
		16	69.9	94.0	207
		16	69.1		
		16	68.3	89.8	192
Cold: -8.8ºC	10-11, 1.6, 10.5, 15	18	62.8		
on day 3		18	72.2	92.7	156
Cold: -9.3ºC	10-11, 1.2, 10.6, 15	18	67.8		
on day 7		18	69.1	90.6	170
Heat: +13.6ºC	10-11, 24.2, 10.5, 15	15	68.4		
on day 7		15	65.7	89.6	185
Heat: +20.2ºC	10-11, 30.7, 10.5, 15	15	66.6		
on day 7		15	67.3	42.0	137
Cold and heat: ±21.1ºC	10-11, 1.1, 22.2	12	69.0	16.1	156
on days 7-10		12	69.0	11.2	135

Literature Cited

Allbaugh, C. A., and J. V. Manz. 1964. Preliminary study of the effects of temperature fluctuations on developing walleye eggs and fry. Progressive Fish-Culturist 26:175-180.

Clapp, D. F., Y. Bhagwat, and D. C. Wahl. 1997. The effect of thermal stress on walleye fry and fingerling mortality. North American Journal of Fisheries Management 17:429-437.

Colby, P. J., R. E. Nicol, and R. A. Ryder. 1979. Synopsis of biological data on the walleye *Stizostedion v. vitreum* (Mitchill 1818). Food and Agriculture Organization of the United Nations, Fisheries Synopsis No. 119.

Heidinger, R. C., R. C. Brooks, D. Leitner, and I. Soderstrom. 1997. Prediction of walleye egg and embryo survival at two stages of development. Progressive Fish-Culturist 59:64-67.

Hokanson, K. E. F. 1977. Temperature requirement of some percids and adaptations to the seasonal temperature cycle. Journal of the Fisheries Research Board of Canada 34:1524-1550.

Jonas, J. L., and D. H. Wahl. 1998. Relative importance of direct and indirect effects of starvation on young walleyes. Transactions of the American Fisheries Society 127:192-205.

Johnson, F. H. 1961. Walleye egg survival during incubation on several types of bottom in Lake Winnibigoshish, Minnesota, and connecting waters. Transactions of the American Fisheries Society 90:312-322.

Johnston, T. A., and J. A. Mathias. 1993. Mortality of first-feeding postlarval walleye (*Stizostedion vitreum*) in culture ponds. Canadian Journal of Fisheries and Aquatic Sciences 50:1835-1843.

Johnston, T. A., and J. A. Mathias. 1994. Feeding ecology of walleye, *Stizostedion vitreum*, larvae: Effects of body size, zooplankton abundance, and zooplankton community composition. Canadian Journal of Fisheries and Aquatic Sciences 51:2077-2089.

Koenst, W. M., and L. L. Smith, Jr. 1976. Temperature requirement of the early life stages of walleye, *Stizostedion vitreum vitreum*, and sauger, *Stizostedion canadense*. Journal of the Fisheries Research Board of Canada 33:1130-11138.

Koonce, J. F., T. B. Bagenal, R. F. Carline, K. E. F. Hokanson, and M. Nagiec. 1977. Factors influencing year class strength of percids: A summary and a model of temperature effects. Journal of the Fisheries Research Board of Canada 34:1900-1909.

Li, S., and J. A. Mathias. 1982. Causes of high mortality among cultured walleyes. Transactions of the American Fisheries Society 111:710-721.

Malison, J. A., J. A. Held, L. S. Weil, T. B. Kayes, and G. H. Thorgaard. 2001. Manipulation of ploidy in walleyes by heat shock and hydrostatic pressure shock. North American Journal of Aquaculture 63:17-24.

Mayer, C. M., and D. H. Wahl. 1997. The relationship between prey selectivity and growth and survival in a larval fish. Canadian Journal of Fisheries and Aquatic Sciences 54:1504-1512.

Schneider, J. C. 1997. Dynamics of a bluegill, walleye, and yellow perch community. Michigan Department of Natural Resources, Fisheries Research Report 2020, Ann Arbor.

Snedecor, G. W., and E. G. Cochran. 1989. Statistical methods, 8th edition. Iowa State University Press, Ames.

von Westernhagen, H. 1988. Sublethal effects of pollutants on fish eggs and larvae. Pages 253-346 *in* W. S. Hoar and D. J. Randall, editors. Fish Physiology, Volume XI, The Physiology of Developing Fish, Part A, Eggs and larvae. Academic Press, San Diego.

Zitzow, R. E. 1991. Extended incubation of walleye eggs with low-flow incubators. Progressive Fish-Culturist 53:188-189.

Paul W. Webb, Editor
Charles H. Pecor, Reviewer
Ellen S. Grove, Desktop Publisher

Approved by Paul W. Seelbach