THERMAL TOLERANCE OF IOWA AND MISSISSIPPI POPULATIONS OF JUVENILE WALLEYE, _STIZOSTEDION VITREUM_.—The Tennessee-Tombigbee Waterway (TTW), completed in Jan. 1985, potentially allows for immigration and/or emigration of fishes between the two once-separated river systems (Boschung, 1989). Ross (1991) indicated
that successful establishment of introduced species occurs mainly in areas of high human disturbance or where there is low species diversity. Successful introductions typically have caused drastic declines in native species. Clearly, the former Tombigbee River system has been impacted by the construction of the TTV and thus possesses the qualities for noncoevolved species to interact.

One species of special concern in the TTV is walleye, *Stizostedion vitreum*, a genetically unique population that is found throughout the Tombigbee River system (Murphy, 1990). This population of walleye is homozygous at four presumptive loci; at the same loci, walleye from eight other locations were highly heterozygous (Murphy, 1990). Billington et al. (1992) have recently indicated that this population of walleye possess a mtDNA haplotype distinct from 67 other walleye populations. Migration and survival of northern walleye through the TTV into the range exclusively occupied by the Mississippi population could have adverse effects on the Mississippi population, due to its apparent low abundance, if these populations interbreed. It has been thought, however, that summer temperatures in Mississippi which reach at least 31.0 C (Arner, 1969; Schultz, 1971; Muncy and Kingerly, 1987), would maintain this unique population because individuals of northern populations would not be able to tolerate such high temperatures over the long summer period. Colby et al. (1979) have indicated that, compared to other populations, the Gulf Coast population of walleye is uniquely tolerant of high temperatures. However, examination of the literature dealing with differences in thermal tolerance among latitudinally different populations of a single species or with species from different thermal habitats indicates that some species do exhibit a clear thermal difference whereas others do not (Hart, 1952; Brown and Fieldmeth, 1971; McCormick and Wegner, 1981). Herke (1969) reported the survival of Iowa walleye fry stocked in a pond in subtropical Florida over a nine- to 10-month period when air temperatures reached 35.5 C. This indicates that temperature may not restrict expansion of northern walleye into the Tombigbee River system.

This study was designed to examine thermal tolerance of juvenile Iowa and Mississippi populations of walleye using the critical thermal maximum (CTM) methodology (Feminella and Matthews, 1984; Beitinger and McCauley, 1990). Juvenile walleyes were used because percid young-of-the-year (YOT) are more tolerant of high temperature than adults (McCauley and Read, 1973; McCauley and Huggins, 1979); thus thermal tolerance of juveniles would provide an "indicator" of the upper temperature limit for the species. Also, I was interested in comparing any thermally induced osmoregulatory dysfunction between the two populations, using plasma osmolality and hematocrit as indicators of stress.

**Materials and methods.**—Iowa walleyes were obtained from the Rathbun Fish Hatchery in Moravia, Iowa; Mississippi walleyes were obtained from the Mississippi Department of Wildlife, Fisheries, and Parks (MDWFP) culture facility in Oxford, Mississippi. Individuals from both populations were separately maintained for 7.5 months in the laboratory in a 145-liter flow-through fiberglass tanks at 23.0 C (dechlorinated tapwater) and fed ad libitum BioKwowa feed (# C-2700). The 12L:12D photoperiod cycle of the laboratory was centered at 1250 h. The CTM methodology used in this study follows that outlined in Palodino et al. (1980) and Feminella and Matthews (1984). Briefly, walleyes were placed singly (n = 15 for each population) into 23.0 C water in a 5-liter boiling flask, and the water was heated at a rate of 1.0 C/min using a mantle heater. Temperature was monitored with a mercury thermometer, and an airstone was placed in the flask to mix the heating water and maintain the oxygen concentration. Two end points were recorded: (1) loss of equilibrium (LOE) and (2) onset of opercular spasms (OS). The fish was then quickly removed and measured (standard length, SL), and blood was collected from the caudal artery in heparinized capillary tubes. Fish were then immediately placed in a lethal bath of MS-222. Blood was centrifuged at 13,460 x g for 4 min, and the hematocrit (% RBC; red blood cell) was recorded. Formed elements were removed, and a 5-µl plasma sample was processed on a Wescor Vapor Pressure Osmometer (Model 5500) to determine plasma osmolality (mOsm/kg). Student's t-test was used to compare the plasma osmolality and hematocrit responses and fish SL between control and treatment individuals for each population. It was also used to compare CTM data between populations for the LOE and OS criteria. All data were analyzed using SPSS PC+ (Ver. 4, Chicago, Illinois) and were considered significant if P < 0.05.

**Results.**—Control individuals of the Iowa population ranged from 152.6-153.6 mm SL (x̄ = 138.4 ± 5.5) and were significantly larger (P < 0.001) than treatment individuals (93.5-142.3 mm SL; x̄ = 120.6 ± 14.3). Control individuals
of the Mississippi population ranged from 103.5–126.9 mm SL ($\bar{x} = 111.9 \pm 6.5$) and were also significantly larger ($P < 0.05$) than treatment individuals (97.5–119.6 mm SL; $\bar{x} = 106.6 \pm 7.5$). The SL of Iowa individuals used in the treatment conditions for the LOE and OS responses were significantly larger than those from Mississippi ($P < 0.01$).

CTM values were not significantly different between Iowa and Mississippi individuals for either the LOE end point or the OS end point (Table 1). Between-population comparisons of plasma osmolality control, hematocrit control, and hematocrit treatment (Table 2) values were not significantly different. Plasma osmolality treatment values were significantly higher for the Mississippi group (Table 2). Within-population comparisons indicated significant increases in treatment plasma osmolality for both Iowa and Mississippi individuals compared to controls (Table 2). There were also significant increases in treatment hematocrit for Iowa and Mississippi groups compared to controls (Table 2).

**Discussion.**—This study indicates that walleye from Iowa and Mississippi acclimated to 23.0°C do not differ in their CTMs; these temperature data are not unusual when compared to other populations of walleye. For example, Hokanson (1977) determined that Minnesota walleye acclimated to 25.8°C had an upper incipient lethal temperature (ULT) of 31.6°C. However, a later study (Hokanson and Koenst, 1986) noted that, if the fish was acclimated to a constant temperature, the ultimate ULT would be higher if the temperature was slowly increased at a rate of 0.5°C/day. For 22.1, 26.0, and 28.0°C acclimation temperatures, they documented ultimate ULTs of 33.0, 34.1, and 34.1°C, respectively. Wrenn and Forsythe (1978) documented an ULT of 34.0°C for 42 mm TL walleye from Pennsylvania. The similarity of responses indicates that the two populations are not all that different in terms of the physiological response to temperature, in spite of some genetic differences. Because temperature appears to be the main difference between the Tennessee and Tombigbee rivers, it appears likely that the populations could mix and the result would be some sort of hybrid. The Mississippi population would thus not maintain its identity. This is tempered by the fact that only juveniles were examined, and we have no data on younger or older developmental stages or reproduction performance in different temperatures. Thus, more data are needed to more comprehensively address temperature as a factor in restricting migration of northern populations into the Tombigbee system.

Individuals from both populations in my study also exhibited significant increases in plasma osmolality and hematocrit compared to control values, which suggests that they were similarly stressed by increased temperature. There is good evidence that osmoregulatory dysfunction occurs at high temperatures due to either thermal inactivation of the mechanism itself or because the osmoregulatory system is not able to com-

**Table 2. Plasma Osmolality (mOsm/kg) and Hematocrit (%) for Iowa and Mississippi Populations of Walleye.** Statistical comparisons to the right of a response are for between-population comparisons (horizontal) whereas those below a population are for within-population comparisons (vertical). All values are reported as $\bar{x} \pm SD$.

<table>
<thead>
<tr>
<th>Responses</th>
<th>Iowa</th>
<th>Mississippi</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasma osmolality</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Controls</td>
<td>$309.0 \pm 11.0$</td>
<td>$315.7 \pm 9.5$</td>
<td>$P &gt; 0.05$</td>
</tr>
<tr>
<td>Treatments</td>
<td>$322.3 \pm 12.3$</td>
<td>$348.0 \pm 10.7$</td>
<td>$P &lt; 0.001$</td>
</tr>
<tr>
<td>Hematocrit</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Controls</td>
<td>$39.7 \pm 3.5$</td>
<td>$39.5 \pm 3.3$</td>
<td>$P &gt; 0.05$</td>
</tr>
<tr>
<td>Treatments</td>
<td>$45.7 \pm 5.1$</td>
<td>$45.7 \pm 2.1$</td>
<td>$P &gt; 0.05$</td>
</tr>
</tbody>
</table>

**Table 1. Critical Thermal Maximum (C) for Iowa and Mississippi Populations of Walleye.** LOE = loss of equilibrium end point. OS = onset of opercular spasm end point. All values are reported as $\bar{x} \pm SD$.

<table>
<thead>
<tr>
<th>Population</th>
<th>Iowa</th>
<th>Mississippi</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOE</td>
<td>34.8 ± 0.3</td>
<td>35.0 ± 0.6</td>
<td>$P &gt; 0.05$</td>
</tr>
<tr>
<td>OS</td>
<td>35.9 ± 0.5</td>
<td>35.8 ± 0.5</td>
<td>$P &gt; 0.05$</td>
</tr>
</tbody>
</table>
pensate for the high levels of passive ion flux in freshwater-acclimated fish at high temperatures (Crawshaw, 1979; Reynolds and Casterlin, 1980). These would produce lower plasma osmolality values which would be opposite to those results obtained in my study. However, Burton (1986) argued that osmolality, Na\(^+\), and Cl\(^-\) in freshwater fish do not typically fall with exposure to increasing temperatures and that K\(^+\) and Ca\(^{++}\) either increase or do not change. Thus, the findings of my study may not be unusual.

I feel that the differences in walleye size between populations and among treatments within populations do not compromise the results of this study because differences in mean SL were minimal, and there was marked overlap in SL within and between populations. Individuals used in this study were small juveniles, and Weatherly (1963) and Horoszewicz (1973) concluded that size did not influence lethal temperatures within juvenile percids. Although McCauley and Read (1973) found ontogenetic differences in thermal preferendum in yellow perch (Perca flavescens), their differences are due to marked differences in size (YOY vs adults), which was not the case for walleye in my study.

In summary, my results indicate that Iowa walleye, as well as the Mississippi walleye, should be able to tolerate the high Mississippi temperature (at least 31 °C). This suggests that migration and survival of juvenile northern walleye into the range exclusively occupied by the Mississippi population via the TTW is probable and might have adverse effects on the Mississippi population, due to its apparent low abundance, if these populations interbreed. However, empirical evidence derived from studies on northern walleye maintained in Mississippi ponds indicates that they usually do not survive high summer temperatures (C. A. Schultz, pers. comm., MDWFP, Aberdeen, Mississippi). This suggests that some additional factor interacts with temperature to produce a lethal combination for northern walleye when held in Mississippi ponds. The most likely factor is oxygen concentration, which can be severely depleted in both ponds and slow moving rivers during the hot summer months in Mississippi.

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Literature Cited


