TEMPERATURE-CAUSED FISH KILL IN A FLOWING GREAT PLAINS RIVER

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ABSTRACT—On 9 July 2002, while sampling a flowing segment of the North Fork Ninnescah River 10 km upstream from Cheney Reservoir, Reno County, Kansas, we observed and collected dead and dying specimens of 5 fish species. We attribute the fish kill to high water temperature, which reached 38.0°C on this day.

RESUMEN—El 9 de julio del 2002, mientras muestreábamos un segmento con corriente del río North Fork Ninnescah, 10 km río arriba de la presa Cheney, en el condado de Reno en Kansas, observamos y recolectamos cinco especies de peces moribundos y muertos. Atribuimos la muerte de los peces a la alta temperatura del agua registrada ese día, la cual alcanzó los 38.0°C.

Effects of temperature are generally sublethal, but in extreme cases temperature and associated stressors can directly cause fish mortality (Beitinger et al., 2000). The most commonly reported instances of mortality attributable to high water temperatures are among fishes that become isolated in streambed pools for extended periods (Tramer, 1977; Matthews et al., 1982; Mundahl, 1990) or in receding lakes (Bailey, 1955). Limited volume of these isolated waters makes them susceptible to rapid changes in physical and chemical conditions. Mortality of fishes attributable to high water temperature is believed to be common, although it is infrequently observed in the field (Bailey, 1955). We are aware of only 2 published reports (Huntsman, 1942, 1946) of temperature-induced mortality among fishes in lotic habitats, both of which describe mortality in coldwater streams. The purpose of this paper is to describe observations of a fish kill in a flowing warmwater stream that we attribute to high water temperature. Our account is necessarily observational because the transience of the event, encountered in the field, precluded experimental manipulation.

On 8 and 9 July 2002, we sampled the North Fork Ninnescah River (37°50′41″N, 97°56′09″W) approximately 10 km upstream from Cheney Reservoir, Reno County, Kansas. Our purpose was to document the composition of the fish assemblage in relation to habitat variables. We sampled this site for approximately one hour, beginning at 1830 h, using 2 seines (1.8 × 3.4 m and 1.8 × 9.1 m, with 5-mm mesh) and making an effort to sample all available habitat types. Captured fish were preserved in 10% buffered formalin. Water quality parameters (temperature, dissolved oxygen, conductivity, and turbidity), stream width, stream depth, and current velocity were recorded in each habitat sampled. In addition to our measurements, hourly water temperature and stream discharge measurements were obtained from the U.S. Geological Survey gaging station (#07144780) located at the site.

We collected 518 fish representing 9 families and 14 species on 8 July 2002 (Table 1). Red shiner (*Cyprinella lutrensis*) and sand shiner (*Notropis stramineus*) were the most common species, collectively representing 80% of the total catch. Northern plains killifish (*Fundulus kansae*) and white perch (*Morone americana*) were the third and fourth most abundant species, respectively. These 2 species combined represented an additional 12% of collected specimens. All other species individually represented fewer than 2% of collected specimens. Physical and chemical conditions (mean ± *SD*) recorded at the time of sampling were: water temperature 35.0 ± 0.17°C, dissolved oxygen concentration 6.93 ± 0.17 mg/L, conductivity 1,115 ± 104 μS/cm, and turbidity 69.2 ± 9.4 NTU. Mean current velocity was 0.37 ± 0.08 m/s, mean stream depth was 20 ± 7.8 cm, and stream width was 34.7 m.

TABLE 1—Fish collected on 8 and 9 July 2002 from the North Fork Ninnescah River upstream from Cheney Reservoir, Reno County, Kansas. Fish collected on 8 July were alive. Fish collected on 9 July were dead or moribund.

	Number collected	
Species	8 July	9 July
Red shiner, *Cyprinella lutrensis*	334	
Sand shiner, *Notropis stramineus*	90	
Northern plains killifish, *Fundulus kansae*	52	
White perch, *Morone americana*	12	28
Emerald shiner, *Notropis atherinoides*	8	
River carpsucker, *Carpoides carpio*	7	1
Western mosquitofish, *Gambusia affinis*	6	
Channel catfish, *Ictalurus punctatus*	6	
Largemouth bass, *Micropterus salmoides*	1	
Green sunfish, *Lepomis cyanellus*	1	
Brook silverside, *Labidesthes sicculus*	1	
White bass, *Morone chrysops*		3
Freshwater drum, *Aplodinotus grunniens*		3
White crappie, *Pomoxis annularis*		2
Total	518	37

On 9 July, we returned at 1730 h to collect additional samples. While sampling, we observed freshly dead or moribund fish in our seine samples. After collecting several afflicted specimens, we ceased seining and collected all dead or moribund fish encountered as recommended by the American Fisheries Society (1992) and Labay and Buzan (1999). Dead or moribund fish were taken for approximately one hour from a 200-m river reach.

We collected 37 specimens that were dead or moribund. Death was observed in 5 species, including white perch, white bass (*Morone chrysops*), freshwater drum (*Aplodinotus grunniens*), white crappie (*Pomoxis annularis*), and river carpsucker (*Carpoides carpio*) (Table 1). White bass, white crappie, and freshwater drum are relatively uncommon in the North Fork Ninnescah River (Johnson, 2004) and were not collected by us on 8 July. The few individuals of these 3 species that we found on 9 July probably were more likely to be found because they were moribund or dead. All species collected on 8 July 2002 also were present in samples taken on 9 July 2002, although fish were not counted; thus, only a subset of the fish community was found dead or moribund.

We measured and recorded standard lengths of white perch collected on both days. Range of lengths for white perch collected on 8 July was 50 to 155 mm ($n = 12$). Lengths of white perch collected dead or moribund on 9 July ranged from 52 to 265 mm ($n = 28$). There was no significant difference between lengths of fish collected alive and dead or moribund ($t = 1.54$, $df = 38$, $P = 0.133$). Range of standard lengths for other affected species collected on 9 July was: white bass, 187 to 222 mm ($n = 3$); freshwater drum, 261 to 315 mm ($n = 3$); white crappie, 104 to 109 mm ($n = 2$); and river carpsucker, 360 mm ($n = 1$).

It seems that high water temperature, which reached 38.0°C on 9 July, resulted in acute heat death of fish in the sampled portion of the river (Fig. 1). Maximum water temperature on 9 July was higher than on any previous day during 2002 at our sampling site and exceeded laboratory-determined thermal tolerances for nearly all of the species collected (Beitinger et al., 2000), especially among those species for which we collected dead and moribund specimens. Dissolved oxygen concentrations were greater than 5.0 mg/L, so it is unlikely that dissolved oxygen was the cause of the fish kill. However, we cannot discount the possibility that some unmeasured and unidentified water-quality parameter was responsible for the fish kill. Because we observed individual fish through all stages of affliction, from initially behaving normally to losing equilibrium and ultimately dying, we are confident that the observed fish kill was due to conditions at this site.

Temperature tolerances vary widely among fish species, and among individuals within species there generally is a positive relationship between temperature tolerance and the temperatures to which fish recently have been exposed (Brett, 1956; Brown and Feldmeth, 1970). Because water temperatures in the North Fork Ninnescah River were elevated (up to 35°C) for several days preceding the observed fish kill, it is not surprising that some species, for example, emerald shiner (*Notropis atherinoides*) and sand shiner, apparently were unaffected by high water temperatures on 9 July 2002, even though ambient water temperatures exceeded their laboratory-determined
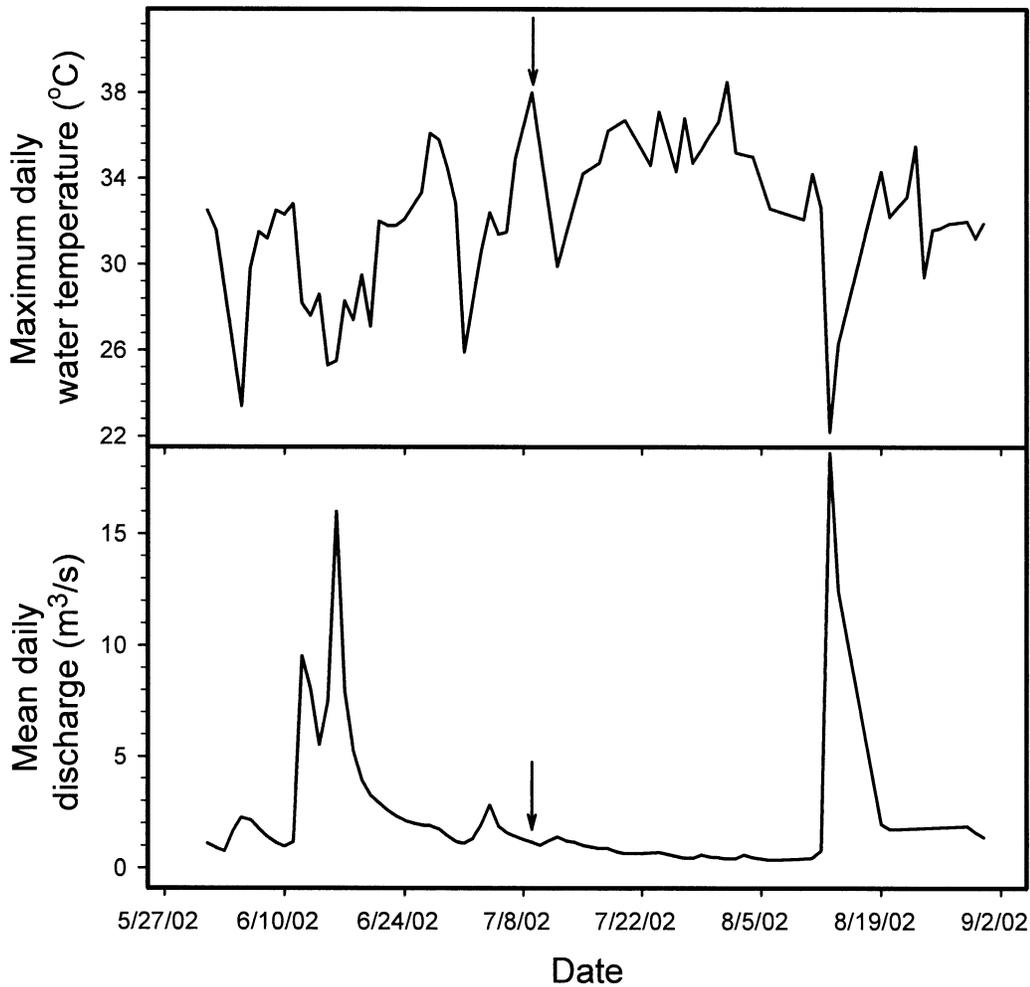
FIG. 1—Maximum daily water temperature (°C) and mean daily discharge (m³/s) during June, July, and August 2002 in the North Fork Ninnescah River upstream from Cheney Reservoir, Reno County, Kansas. Data were obtained from a U.S. Geological Survey gaging station (#07144780) located at the sampling site. Arrows indicate 9 July 2002, the day of the observed fish kill.

tolerances (Matthews and Maness, 1979; Smale and Rabeni, 1995). White perch is native to coastal drainages ranging from Nova Scotia south to South Carolina and is most abundant in the Hudson River and Chesapeake Bay (Burgess, 1980). White perch was inadvertently introduced into Cheney Reservoir in 1994 and apparently was the species most affected by high water temperatures in the North Fork Ninnescah River. Of the other species affected, 3 (white bass, white crappie, and freshwater drum) are native to drainages farther east in Kansas, but were not likely native to the Nin-

nescah River basin (Cross, 1967; M. Eberle, pers. comm.). In western Kansas, which includes the Ninnescah River basin, these 3 species occur in impoundments and nearby stream segments (Cross, 1967). Thus, they might be more susceptible to heat stress when they move into shallow river segments during the summer and are unable to move into cooler microhabitats. Interestingly, it did not appear that size of fish was an important factor contributing to the death of white perch that we observed.

Reservoir construction, groundwater with-

drawal, and irrigation diversions have resulted in extensive modifications of streams and rivers throughout the Great Plains. These changes have altered the discharge of these systems, which has caused streams and rivers to narrow and deepen and become confined to a single unbraided channel, in which a greater portion of the stream channel is shaded by gallery forests (Friedman et al., 1998). Associated with these changes in stream habitats has been a decrease in the distribution and abundance of several obligate stream fishes that usually are attributed to competition with, and predation by, species that historically were absent or uncommon in these streams (Cross and Moss, 1987; Pfleiger and Grace, 1987; Bonner and Wilde, 2000). Our observations suggest that the composition of the present fish assemblages might be structured, in part, by extremes in physical and chemical conditions. Among these, high water temperatures during summer periods of low discharge probably limit the ability of some species to inhabit these streams, even when they maintain some flow.

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FOLLICULAR DEVELOPMENT AND OVULATION DETERMINED BY ULTRASOUND IMAGING IN THE VIVIPAROUS LIZARD *BARISIA IMBRICATA* (REPTILIA: ANGUIDAE)

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ABSTRACT—Ovarian follicular development and ovulation were studied by ultrasound scanning in the Mexican viviparous lizard *Barisia imbricata*. A linear ultrasound unit with variable capacity from 5 to 10 MHz was used. Vitellogenic follicle diameters ranged from 3.3 to 9.8 mm and were present in the lizards between September and December. Also, corpora lutea and uterine eggs were identified. The ultrasound is an excellent non-invasive technique to determine seasonal reproductive changes and can be combined with other techniques to monitor the reproductive process.

RESUMEN—El desarrollo folicular del ovario y la ovulación fueron estudiados en la lagartija vivípara mexicana *Barisia imbricata* mediante la técnica de ultrasonido. Se utilizó una unidad linear con capacidad variable de entre 5–10 MHz. Los diámetros de folículos vitelogénicos variaron de 3.3 a 9.8 mm y estuvieron presentes entre septiembre y diciembre. Cuerpos lúteos y huevos uterinos también fueron identificados. El ultrasonido es una excelente técnica no destructiva para determinar los cambios reproductivos estacionales y puede ser combinado con otras técnicas para el seguimiento del proceso reproductor.

Numerous papers published since 1980 have documented the gonadic changes that occur during reproductive cycles of several reptiles. Most information concerning ovarian follicular dynamics has been obtained through the sacrifice of females of several species of Squamata, principally lizards (for review see Xavier, 1987; Uribe et al., 1996). However, several reports show that some populations of reptiles are at risk of extinction (Wilson and McCranie, 2004); therefore, the sacrifice as a method to determine the reproductive condition could be replaced by alternative techniques that allow study of the reproductive process without killing the organism. In lizards, several non-destructive and non-invasive techniques have been used, such as laparoscopy (Schildger et al., 1993), blood analyses (Bourne and Seamark, 1972), radiography (Schildger et al., 1993), and ultrasonography (Schildger et al., 1996), to study ovarian changes. We were interested to learn the potential of the non-invasive techniques to study of the reproductive biology of viviparous Mexican lizards. The goal of this study was to evaluate the efficacy of ultrasound scanning to determine follicular de-