The effects of potential climate change-related river water temperature shifts on the reproductive success of the redside dace (*Clinostomus elongatus*)

August J. Steigmeyer, Kelly A. Heilman, Ray Heithaus[a], Trevor E. Pitcher[b]

[a]Department of Biology, Kenyon College; [b]Department of Biology, University of Windsor

Introduction

Male fish with the most competitive sperm have been shown to produce the fittest offspring. These factors have influenced the females' mate selection (Neff and Pitcher 2005).

Though the fish's individual characteristics can be indicators of sperm quality (Neff and Pitcher 2005), environmental variables including pH, ion concentrations, osmotic pressure and temperature, can affect the survival and motility factors of the cells (Alavi and Cosson 2005, 2006).

Fish sperm have a short lifespan but their viability in that short time can be affected by the temperature of the water in which they are activated. Swimming velocities of Atlantic Cod sperm decrease as temperature increases and this becomes more apparent the longer the sperm are swimming (Purchase et al. 2010).

Annual river water temperatures in the U.S. have increased significantly and will continue to rise, based on prediction models (Kaushal et al. 2010). These temperature changes in the coming years could greatly affect fish reproduction.

The Redside Dace minnow is an indicator of the health of small streams. The most successful populations exist in clear water alongside wooded areas (Ohio DNR). We chose to study this organism because it is already endangered in parts of North America and would most likely be one of the first species affected by a shift in the average river water temperature.

Hypothesis

H_0: Water temperature variation will not effect the functions of male Redside Dace sperm.
H_A: Variations in water temperature will affect the lifespan and/or motility of Dace sperm cells.

Prediction

Increases in water temperature, even by just a few degrees, will begin to negatively affect the short lifespan of the Dace sperm cells. The total number of moving cells in the sample and their lifespan will both decrease. The linearity of their movement will decrease, most likely causing the cells to spin and the velocity of the cells will decrease upon activation.

Methods

- Redside Dace sperm and egg samples were collected from individuals from three different streams in Knox County, OH, designated RSD1, RSD2, and Rathburn.
- Motility trials began 1-3 hours after sperm collection. A sample of river water was chilled to a desired temperature and used to activate 1 µl of sperm on a microscope slide. The sperm cell movement was recorded with a video camera and stored on a DVD for later analysis. This process was repeated in triplicate for each individual at each temperature (15, 18 and 20 degrees C).
- Computer software tracked the motion of each sperm cell and analyzed the sample in terms of total percent motility, velocity and linearity.
- Seasonal temperature data were recorded continuously in the stream with submerged probes throughout the fieldwork phase (May-June 2011).
- All data were analyzed using either Minitab 17 or SPSS 18 software programs. The hypothesis that there would be plasticity of sperm metrics in response to differences in temperature was tested using an ANOVA, as well as a repeated measures (nested) ANOVA. A General Linear Model was used to test for differences among individuals for each sperm metric.

Results

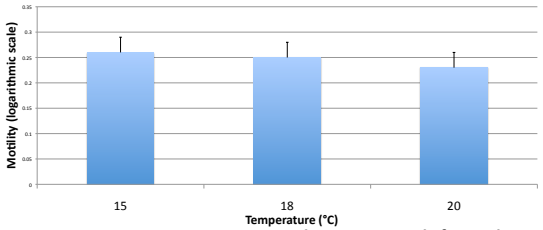

Fig. 1 Average sperm motility at 5 seconds for each water temperature

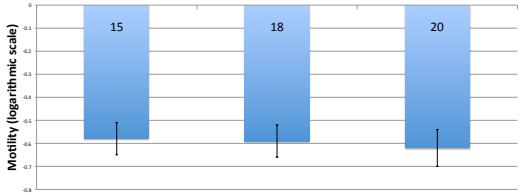

Fig. 2 Average sperm motility at 10 seconds for each water temperature

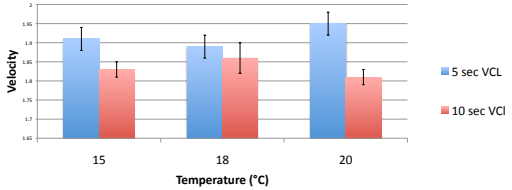

Fig. 3 Average sperm velocity at each water temperature

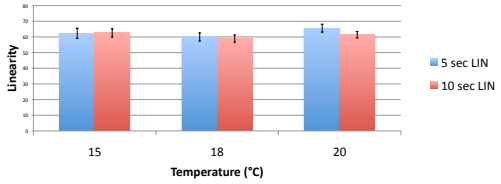

Fig. 4 Average sperm linearity at each water temperature

Results and Discussion

The total number of sperm cells moving 5 seconds after activation seems to decline as temperature increases, but the results are not significant (Fig. 1). This suggests that the current average temperature in the stream (15 degrees) could be more conducive to cell movement but a difference of 5 degrees is not likely to cause any serious problems with the sperm cell lifespan.

The number of cells moving at 10 seconds seems to increase with a temperature increase (Fig. 2). This suggests that the sperm cells could take longer to activate under higher temperatures. Again, though, a difference of 5 degrees will not significantly affect cell motility. This trend, though not significant, could suggest a pattern that would become more apparent with more extreme temperatures, perhaps at 25 or 30 degrees (closer to the temperatures that affected Atlantic Cod sperm in the Purchase et al. study)

The velocities were higher 5 seconds after activation than 10 seconds at all temperatures (Fig. 3). Because the lifespan of the sperm is short, it logically slows down as time increases. The difference in average velocity, though, is not significant between any of the temperatures or between 5 and 10 seconds within the temperatures, except at 20 degrees. At 20 degrees the velocity was significantly higher at 5 seconds than at 10 seconds, suggesting that the cells may expend more energy early on at a higher temperature and slow their velocity more quickly. This is another trend that is not significant at our temperature intervals, but which could become more extreme at higher temperatures, as evidenced by the significance at 20 degrees.

The linearity differed little between the three temperatures (Fig. 4). Temperature seems to have no effect on the directional movement of the cells. Based on this evidence we reject our hypothesis that small increases in temperature (up to 20 degrees) will cause irregular cell movement, such as spinning.

The predicted rise in average river water will most likely not affect Redside Dace sperm survivability or viability. The parameters measured here determine the lifespan, speed and motion direction of an activated sperm cell and are strong indicators of sperm health under certain conditions. Twenty degree water temperatures will not affect the activation or viability of these cells.

We did observe some trends that follow a temperature increase. Though none of them were significant, future research could increase the temperature beyond predicted values to determine the temperature at which sperm quality begins to decline. This will give us a better idea of the "tipping point" and a better understanding of how the extremes of climate change will affect sensitive stream indicator organisms.

References Cited

Alavi, Sayyed and Jacky Cosson, 2005. *Cell Biology International*. 29: 101-110

Alavi, Sayyed and Jacky Cosson, 2006. *Cell Biology International*. 30: 1-14

Kaushal et al., 2004. *Frontiers in Ecology and the Environment*. 8: 461-466

Neff, Bryan D. and Trevor E. Pitcher, 2005. *Molecular Ecology*. 14: 19-38

ODNR, 2010. "Redside Dace." ODNR.com

Acknowledgements

We would like to acknowledge the help of Ian Butts and Ali Tahmasebi in collecting some of the sperm and egg samples. We would like to thank Dave Heithaus for the use of the Brown Family Environmental Center lab space.