The Effects of Developmental Temperature on Fecundity of *Daphnia lumholtzi*, an Exotic Zooplankter

Denae R. Nash[1] and Charles L. Pederson[2]

[1]Biology Department, Our Lady of the Lake University, San Antonio, Texas and [2]Department of Biological Sciences, Eastern Illinois University, Charleston, Illinois

Introduction

Daphnia lumholtzi Sars is a species of crustacean zooplankton native to Africa, India, and Australia that is believed to have been introduced along with stocking of Nile perch into Fairfield Reservoir, Texas in the early 1980's. Within two decades it has spread throughout most of the central southeastern United States (**Figure 1**). *Daphnia lumholtzi* typically have a late May appearance with a sharp midsummer population peak. Like most exotics, this species usually invades disturbed habitats which tend to have some other shared characteristics, including large surface areas, high water clarity, relatively higher water temperatures, and lower total phosphorus, and chlorophyll *a* levels.

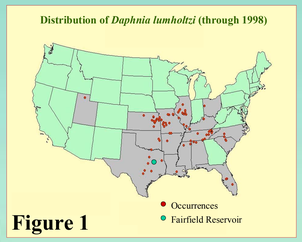

Figure 1

Daphnia lumholtzi

Daphnia lumholtzi has extreme morphological features which may interfere with feeding by natural predators (**Figure 2**). As a result, *Daphnia lumholtzi* may cause disruptions in the food chain that could have serious ecological and economic implications.

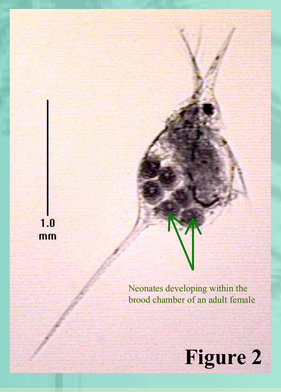

Figure 2

Newton Lake

Temperature optima in excess of 25 °C have been reported for *Daphnia lumholtzi* by other investigators. Our objective was to investigate population dynamics of this exotic zooplankter in Newton Lake (**Figure 3**), a cooling lake for a coal-fired power plant in Jasper County, IL. This reservoir has a surface water area of 667.7 hectares, a shorelength of 94.9 km, and a maximum depth of 12.2 m. We sampled from 6 different location in the lake, three from the warm arm and three from the cold arm (**Figure 4**).

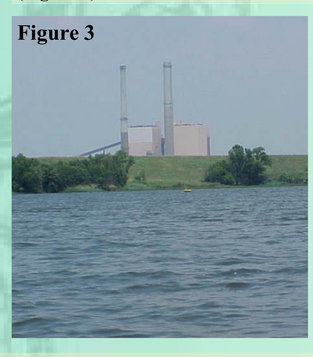
Figure 3

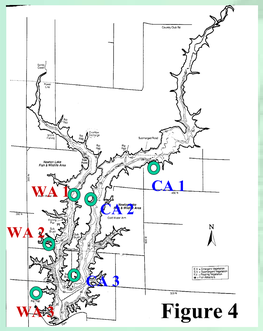

Figure 4

Field Sampling at Newton Lake

Every two weeks, from May 22, 2002 through July 3, 2002, two plankton samples were collected from each site by doing vertical tows, surface to bottom, with a Wisconsin plankton net. Water samples also were obtained in order to determine total phosphorus, and chlorophyll *a* levels. In addition, profiles of temperature, pH, dissolved oxygen, and light were made to determine the trophic state of the lake, and for consideration of variables that might affect population dynamics of *D. lumholtzi.* During our six week sampling period, trends in Newton Lake were towards lower total phosphorus concentrations, relatively stable algal standing crop as indexed by chlorophyll *a*, and increased water clarity. Therefore, late in our sampling period Newton Lake presumably became an ideal environment for *D. lumholtzi* and we would have expected to see increasing population densities. However, by 3 July, *D. lumholtzi* had disappeared from the Newton Lake zooplankton at all sites we had monitored (**Figure 5, at right**).

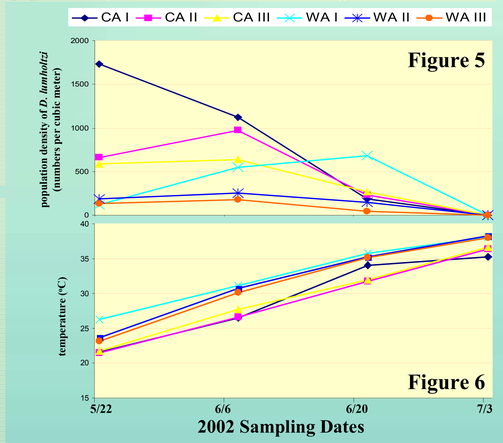

Figure 5

What Happened to *D. lumholtzi* in Newton Lake?

While other environmental factors tended more toward the presumed optimum, temperature increased dramatically at all sites from 22 May through 3 July, 2002 (**Figure 6, at right**). While gradual increase in temperature may have little impact on survival of adults, a decline in fecundity may have resulted. We believe that individuals may be acclimated to a relatively narrow temperature range while in the brood chamber of their parent (again see **Figure 2**). We predicted that upon "hatching," individuals placed outside this temperature at maturity would experience decreased reproductive success. We designed laboratory experiments to investigate the effects of **temperature during development** and subsequent **exposure temperature during maturation** on life history characteristics of adult *Daphnia lumholtzi.* **We defined the "developmental period" as time spent spent by offspring in the brood chamber of an adult female, and the "maturation period" as extending from hatching through the end of the first adult instar, at which time either ephippia were produced or a first clutch of neonates was released.**

Figure 6

Methodology

Live samples collected from the CA 2 site were maintained initially at 24°C and then were split into 3 mass cultures grown at 23°, 25°, and 28°C. From these mass cultures gravid females were put into individual cultures to generate neonates for each of the three developmental temperatures. Neonates which developed at each of these temperatures were randomly assigned to one of three exposure temperatures (**Figure 7**).

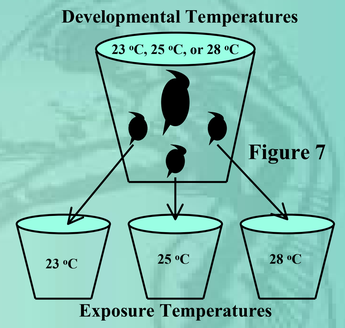

Figure 7

"Exposure organisms" were monitored daily and the following data were recorded: **mortality**, **age at first reproduction**, **number producing ephippia** or the **number of neonates produced at the end of the first adult instar**.

No Mortality Observed Following Development at 25 °C

Organisms undergoing development at 25°C, experienced no mortality regardless of subsequent exposure temperature (**Figure 8, at right**). However, mortality was observed in those individuals developing at 23° and 28°C suggesting that both 23° and 28°C may be stressful environments for *D. lumholtzi*.

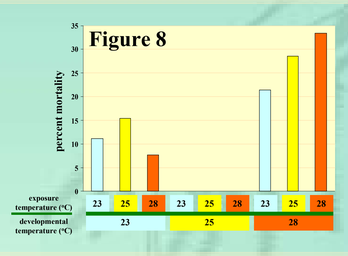

Figure 8

Lower Temperature During Development and Maturation Decreases Age at 1st Reproduction

A significant increase in age at first reproduction was observed in individuals that developed at 23°C when compared to those which developed at 25°C ($p = 0.003$) and 28°C ($p = 0.0001$). Differences in reproductive maturity of individuals developed at 25°C and 28°C were not significant ($p > 0.05$) (**Figure 9, at right**).

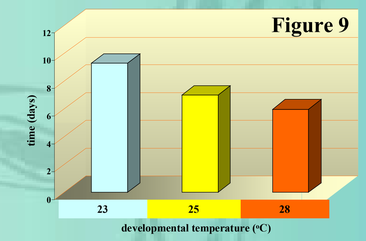

Figure 9

Temperature Moderation Delays Reproductive Maturity

Two-factor ANOVA revealed a significant increase ($p = .024$) in age at first reproduction in individuals transferred to 25°C when compared to those transferred to 23°C, regardless of temperature during development. Time to maturation was no different ($p > 0.05$) upon transfer to 28°C when compared to that observed at the two lower temperatures (**Figure 10, at right**). Interaction ($p > 0.05$) between independent variables was not significant.

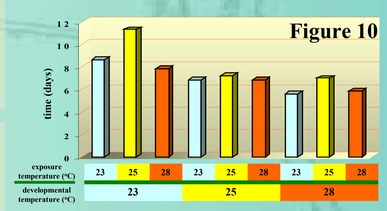

Figure 10

Elevated Temperature During Maturation Increases Production of Ephippia

Individuals that were transferred to 23°C did not produce ephippia at maturity, regardless of the temperature regime during their developmental period. In contrast, exposure to 28°C following development at lower temperatures increased production of ephippia (**Figure 12, below**). A small number of individuals produced ephippia at maturity in 25°C (one individual transferred from 25°C and one from or 28°C).

Development at Moderate Temperature Increases 1st Clutch Size

Exposure temperature during maturation had no effect on clutch size. However, individuals that developed at 25° had significantly larger average first clutch size (**Figure 10, at right**) than those which developed at 23°C ($p = 0.016$). Although the not statistically significant ($p > 0.05$), clutch size also appeared to be decreased by development at 28°C (vs. 25°C).

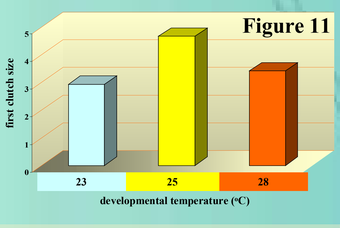

Figure 11

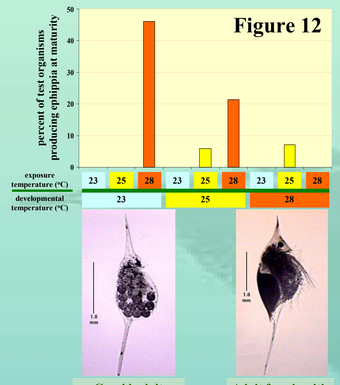

Figure 12

Gravid adult female with viable eggs contained in brood chamber

Adult female with "saddle-shaped" ephippium at end of adult instar

Conclusions

In general, development at a moderate temperature (25°C) facilitates survival regardless of the direction of temperature change during maturation, whereas development at more extreme temperatures typically compromises adult survival.

Exposure to a moderate temperature (25°C) upon "hatching" results in a significant delay in maturation, suggesting that individuals may forego reproduction during periods of more benign environmental conditions. This delay in reproductive maturity may be offset, at least in part, by production of significantly larger clutches by neonates born to females at this temperature.

Although development at extreme temperatures hastens reproductive maturity, these individuals tend to produce smaller clutches of neonates at the end of the first adult instar. Furthermore, individuals undergoing maturation at temperatures above those at which they developed are more likely to produce ephippia at reproductive maturity than are those in a cooler or more stable environment. Production of fewer viable offspring, albeit earlier in the life span, may precipitate a decline in population density when temperatures are increasing (or decreasing).

Data from laboratory experiments lead us to reject the null hypotheses that developmental temperature and exposure temperature have no effect on fecundity of *D. lumholtzi*. We believe that *in situ* population dynamics may be explained by acclimation of individuals during the developmental period (i.e., the time from deposition of eggs in the brood chamber of an adult female to the release as neonates upon molting) as well as during the period of maturation upon hatching.

Acknowledgements

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