Local adaptation of *Daphnia pulicaria* to toxic cyanobacteria

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Introduction

A well-established tenet in limnology holds that the taxonomic composition of summer phytoplankton assemblages shifts with phosphorus enrichment toward greater dominance by cyanobacteria. One important consequence of this shift toward cyanobacteria with eutrophication is that summer phytoplankton assemblages in eutrophic lakes are relatively resistant to zooplankton grazing. However, one recent study showed that zooplankton from a lake in Europe adapted to tolerate bloom-forming cyanobacteria in their diet after several decades of cultural eutrophication. This project aimed to determine if adaptation by grazers to toxic prey occurs across lakes that vary in nutrient concentration.

Hypothesis

Daphnia pulicaria clones isolated from high-nutrient, cyanobacteria-abundant lakes are more tolerant of toxic *Microcystis aeruginosa* than clones isolated from low-nutrient lakes.

Methods

Twenty-two *D. pulicaria* clones were isolated from six lakes in southern Michigan. The six lakes were grouped into two categories based on the midpoint of ranges of summer total phosphorus (TP) concentration, low TP (9 - 13 $\mu g\ L^{-1}$) and high TP (31 - 235 $\mu g\ L^{-1}$). Two juvenile growth experiments were conducted and data from the two experiments were pooled for all analyses. Neonates (<24 hours old) of each clone were transferred individually into 100 ml glass beakers filled with 80 ml of glass-fiber filtered lake water, and a random subset of neonates was transferred individually to a dried and tared weighing tin for initial mass estimates (W_i). Neonates were fed either *Ankistrodesmus falcatus*, a nutritious green alga, or a single-celled toxic strain of *Microcystis aeruginosa* (microcystin quota: 36 $\mu g\ mg^{-1}$ C) at growth-saturating concentrations (1.5 mg C L^{-1}) and transferred to new beakers with fresh medium and food daily. On day 3 (W_f) of the experiments, each animal was transferred individually to a tared weighing tin, dried, and weighed. Instantaneous somatic growth rate (g, d^{-1}) was calculated for each beaker as: $\{[\ln(W_f) - \ln(W_i)]/3\}$. We calculated a relative index of growth inhibition by *Microcystis* for each clone as: $(g_a - g_m)/g_a$, where g_a is growth rate on *Ankistrodesmus* and g_m is growth rate on *Microcystis*. Growth responses were averaged across clones for each lake, and differences between low-TP and high-TP lakes assessed via two-tailed *t*-tests, with lakes as replicates.

Results

Daphnia clones generally grew well on a diet of *Ankistrodesmus*, and there was no significant difference in growth on this diet between lake categories ($p > 0.40$), despite substantial overall variation in growth rate. As expected, all clones grew poorly on the *Microcystis* diet. More importantly, *D. pulicaria* from high-TP lakes grew significantly better, on average, than *D. pulicaria* from low-TP lakes on the *Microcystis* diet ($p < 0.02$). On average, *D. pulicaria* from low-TP lakes lost weight when fed *Microcystis* (growth < 0, *t*-test, $p < 0.04$, $n = 3$), while *D. pulicaria* from high-TP lakes did not (growth <0, *t*-test, $p > 0.30$, $n = 3$).

Conclusions

We quantified within-species variation in the tolerance of the large lake-dwelling daphnid, *D. pulicaria*, to toxic cyanobacteria in the diet. Juvenile growth rates on diets consisting of 100% *Ankistrodesmus* or 100% toxic *Microcystis* were compared for *D. pulicaria* clones isolated from lakes expected to have low and high levels of bloom-forming cyanobacteria during summer. Growth rates of clones isolated from high-nutrient lakes were higher, and showed less relative inhibition, on the cyanobacterial diet, compared to clones isolated from low-nutrient lakes. Our results suggest that *D. pulicaria* populations exposed to high cyanobacterial levels over long periods of time can adapt to being more tolerant of toxic cyanobacteria in the diet.