Main question:

Does the temperature history of rotifers affect competition with protists?

Sub-questions:

1. Did the evolution period lead to changes to rotifers’ response to temperature?
2. Do rotifers have a competitive response to the protist?
3. Do rotifers have a competitive effect on the protist?

1. Population growth rate (*r*)

Table 1. Effects of evolved temp, current temp, and competition on rotifer growth rate. Three-factor type III ANOVA. Data are log-transformed to meet test assumptions.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Predictor | SS | df | *F* | *p* |
| Evolved temperature | 0.0285 | 1 | 0.1747 | 0.6772 |
| Current temperature | 1.5953 | 1 | 9.7838 | 0.0025\*\* |
| Competition | 0.0765 | 1 | 0.4694 | 0.4955 |
| Evolved T x Current T | 0.2332 | 1 | 1.4302 | 0.2356 |
| Evolved T x Competition | 0.2020 | 1 | 1.239 | 0.2694 |
| Current T x Competition | 0.8302 | 1 | 5.0913 | 0.0271\*\* |
| Evolved T x Current T x Competition | 0.1287 | 1 | 0.7895 | 0.3772 |
| Residuals | 11.74 | 72 |  |  |

Table 2a. Effects of current temp and competition on protist growth rate. Two-factor type III ANOVA. Data are log-transformed to meet test assumptions.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Predictor | SS | df | *F* | *p* |
| Current temperature | 6.2274 | 1 | 30.9951 | <0.001\*\*\* |
| Competition | 0.6339 | 2 | 1.5774 | 0.2159 |
| Current T x Competition | 2.1513 | 2 | 5.3536 | 0.0076\*\* |
| Residuals | 10.8495 | 54 |  |  |

Table 2b. Comparisons among competition treatment effects on log-transformed protist growth rate. All p-values are Tukey’s HSD-adjusted.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Current T | Comparison | *estimate* | SE | *df* | *t* | *p* |
|  | control - rotif25 | -0.3453 | 0.2005 | 54 | -1.7224 | 0.2062 |
| 25 °C | control - rotif30 | -0.248 | 0.2005 | 54 | -1.2369 | 0.4369 |
|  | rotif25 - rotif30 | 0.0973 | 0.2005 | 54 | 0.4854 | 0.8785 |
|  | control - rotif25 | 0.406 | 0.2005 | 54 | 2.0253 | 0.1159 |
| 30 °C | control - rotif30 | 0.5989 | 0.2005 | 54 | 2.9879 | 0.0116\* |
|  | rotif25 - rotif30 | 0.1929 | 0.2005 | 54 | 0.9625 | 0.6035 |

i. Evolution of temperature response in rotifers (*r*)

The growth rate of rotifers did not differ between the two evolutionary histories of temperature (F1,72 = 0.469, p = 0.677; Table 1).

ii. Rotifer competitive response (*r*)

Competition did affect rotifer growth rate, but was dependent on current temperature (*F*1,72 = 5.091, *p* = 0.0271; Table 1). Growth rate was nearly doubled (98% higher, back-transformed ES) in the absence of a competitor at 30 °C (*estimate* = 0.682 ± 0.13 SE, *t*72 = 5.34, *p* < 0.001) but competition had only a weak effect on growth rate at 25C (*estimate* = 0.27 ± 0.13 SE, *t*72 = 2.08, *p* = 0.041). In the absence of competition, protists grew faster (51%, back-transformed ES) at 30 °C than at 25 °C (*estimate* = 0.41 ± 0.13 SE, *t*72 = 3.23, *p* = 0.002), whereas temperature had no detectable effect when a competitor was present (*p* = 0.98).

iii. Rotifer competitive effect (*r* of protists)

Competition affected the growth rate of protists, but the effect was dependent on current temperature (*F*1,54 = 5.354, *p* = 0.008; Table 2a). Post-hoc comparisons using Tukey’s HSD-adjusted p values of the levels of competition (competition with rotifers from each evolutionary history, and a control without rotifers) show protist growth rate was further dependent on the evolutionary history of their rotifer competitors. At a current temperature of 30 °C, protist growth rate was about 46% lower (back-transformed data) in the presence of rotifers, but only if the rotifers evolved at 30 °C (*estimate* = 0.599 ± 0.200 SE, *t*54 = 2.988, *p* = 0.0116). At the same current temperature of 30 °C, rotifers with an evolutionary history of 25 °C did not have an effect on protist growth rate (*estimate* = 0.406 ± 0.200 SE, *t*54 = 2.025, *p* = 0.1159). Protist growth rate was unaffected by the presence of competitors when the current temperature was 25 °C (all *p* > 0.05, Table 2b).

2. Carrying capacity (*K*)

Table 3. Effects of evolved temp, current temp, and competition on rotifer carrying capacity. Three-factor type III ANOVA.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Predictor | SS | df | *F* | *p* |
| Evolved temperature | 945.657 | 1 | 12.1784 | <0.0001\*\*\* |
| Current temperature | 749.6261 | 1 | 9.6539 | 0.0027\*\* |
| Competition | 6511.885 | 1 | 83.8615 | <0.0001\*\*\* |
| Evolved T x Current T | 132.7884 | 1 | 1.7101 | 0.1951 |
| Evolved T x Competition | 14.9498 | 1 | 0.1925 | 0.6621 |
| Current T x Competition | 170.6975 | 1 | 2.1983 | 0.1425 |
| Evolved T x Current T x Competition | 33.3361 | 1 | 0.4293 | 0.5144 |
| Residuals | 5590.8346 | 72 |  |  |

Table 4. Effects of current temp and competition on protist growth rate. Two-factor type III ANOVA.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Predictor | SS | df | *F* | *p* |
| Current temperature | 705289.3435 | 1 | 35.8815 | <0.001 |
| Competition | 1144484.2236 | 2 | 29.1127 | <0.001 |
| Current T x Competition | 806705.5098 | 2 | 20.5205 | <0.001 |
| Residuals | 1061428.3078 | 54 |  |  |

i. Evolution of temperature response in rotifers (*K*)

Evolved temperature affected the carrying capacity of rotifers independent of current temperature and competition (*F*1,72 = 12.1784, *p* = <0.001; Table 3). The carrying capacity of rotifers that evolved at 25 °C was 12.5% (± 3.6% SE) higher than those that evolved at 30 °C (*estimate* = 6.88 ± 2.66 SE, *t*72 = 3.490, *p* = <0.001).

ii. Rotifer competitive response (*K*)

Competition affected the carrying capacity of rotifers independent of current temperature and evolved temperature (*F*1,72 = 83.8615, *p* = <0.001; Table 3). Rotifer carrying capacity was 36.4% higher in the absence of the protist competitor (*estimate* = 18.0 ± 1.97, *t*72 = 9.158, *p* = <0.001).

iii. Rotifer competitive effect (*K* of protists)

Competition affected the carrying capacity of protists, but the effect was dependent on current temperature (*F*1,54 = 20.5205, *p* = <0.001; Table 4). Protist carrying capacity was overall 36% lower in the presence of rotifer competitors, but only at a current temperature of 25 °C (estimate = -395.9 ± 59.2, t54 = -6.681, p = <0.001). Protists had a xx% lower carrying capacity at 25 °C when compared to 30 °C, but only when competing with rotifers that evolved at 25 °C (stats). When competing with rotifers that evolved at 30 °C, protist carrying capacity was unaffected by current temperature (stats). In the absence of rotifers, protist carrying capacity was xx% higher at 25 °C (stats)