Long-term effects of CO$_2$ and temperature on the pennate diatom *Cylindrotheca fusiformis*

Michael Y. Roleda, Yuanyuan Feng, Feixue Fu, Avery O. Tatters, Catriona L. Hurd, Philip W. Boyd, and David A. Hutchins
Diatom: Primary production

- Marine diatoms: ~40% of marine and ~20% of total global primary production
- CO$_2$: limiting for large diatoms (Riebesell et al., 1993)
- Phytoplankton community shift to diatom-dominant assemblage after CO$_2$ enrichment (Tortell et al. 2002)

Question 1: How does natural phytoplankton community in the Southern Ocean respond to Global Climate Change?

Question 2: Are there intraspecific differences in adaptation to warming and acidification?
Experimental design: Collection site
Experimental design: Preceding study

- Follow changes in community structure, biogeochemical ratios & primary productivity.
- Obtain culture isolates of the “winners” in all treatments.

Natural phytoplankton community

14°C 180ppm
14°C 380ppm
14°C 750ppm

January 2010
14 days incubation

19°C 180ppm
19°C 380ppm
19°C 750ppm

(Tatters et al., in prep)
Experimental design
Experimental design: This study

Natural phytoplankton community

- 14°C 180ppm
- 14°C 380ppm
- 14°C 750ppm

January 2010
14 days incubation

- 19°C 180ppm
- 19°C 380ppm
- 19°C 750ppm

(Tatters et al., in prep)

C. fusiformis

- 14°C 180ppm
- 14°C 380ppm
- 14°C 750ppm

2012
> 300 generations
NZ versus USA

- 14°C 180ppm
- 14°C 380ppm
- 14°C 750ppm

(This study)
Result: Growth rates
\( (n=3, \pm \text{ SE}) \)

NZ-adapted clone

USA-adapted clone

<table>
<thead>
<tr>
<th>Factor</th>
<th>Significance ((P))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temp.</td>
<td>0.674</td>
</tr>
<tr>
<td>( p\text{CO}_2 )</td>
<td>0.778</td>
</tr>
<tr>
<td>Temp. ( \times ) ( p\text{CO}_2 )</td>
<td>0.010*</td>
</tr>
</tbody>
</table>

19\(^{\circ}\)/180 > 14\(^{\circ}\)/180 \( \leq \) 14\(^{\circ}\)/750 \( \geq \) 14\(^{\circ}\)/380 = 19\(^{\circ}\)/380 = 19\(^{\circ}\)/750
Result: Chlorophyll a
(n=3, ± SE)

NZ-adapted clone

USA-adapted clone

<table>
<thead>
<tr>
<th>Factor</th>
<th>NZ-adapted clone</th>
<th>USA-adapted clone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temp.</td>
<td>0.602</td>
<td>&gt; 0.001*</td>
</tr>
<tr>
<td>$pCO_2$</td>
<td>0.133</td>
<td>0.029*</td>
</tr>
<tr>
<td>Temp. × $pCO_2$</td>
<td>0.383</td>
<td>0.028*</td>
</tr>
</tbody>
</table>

$19^\circ C/750 > 19^\circ C/380 \geq 19^\circ C/180 \geq 14^\circ C/750 = 14^\circ C/180$
Result: POC

(n=3, ± SE)

NZ-adapted clone

<table>
<thead>
<tr>
<th>Temp.</th>
<th>14°C</th>
<th>19°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>180 ppm</td>
<td>180 ppm</td>
<td></td>
</tr>
<tr>
<td>380 ppm</td>
<td>380 ppm</td>
<td></td>
</tr>
<tr>
<td>750 ppm</td>
<td>750 ppm</td>
<td></td>
</tr>
</tbody>
</table>

USA-adapted clone

<table>
<thead>
<tr>
<th>Temp.</th>
<th>14°C</th>
<th>19°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>180 ppm</td>
<td>180 ppm</td>
<td></td>
</tr>
<tr>
<td>380 ppm</td>
<td>380 ppm</td>
<td></td>
</tr>
<tr>
<td>750 ppm</td>
<td>750 ppm</td>
<td></td>
</tr>
</tbody>
</table>

Factor  : Significance (P)
Temp.   : 0.965
$pCO_2$ : 0.395
Temp. × $pCO_2$ : 0.680

Factor  : Significance (P)
Temp.   : > 0.001*; 14°C>19°C
$pCO_2$ : 0.089
Temp. × $pCO_2$ : 0.266
Result: PON
(n=3, ± SE)

NZ-adapted clone

USA-adapted clone

Factor: Significance (P)
Temp.: 0.061
pCO₂: 0.599
Temp. × pCO₂: 0.501

Temp.: > 0.001*
pCO₂: 0.002*
Temp. × pCO₂: 0.001*

14°C/180 > 14°C/380 = 14°C/750 > 19°C/180 = 19°C/380 = 19°C/750
Summary:

<table>
<thead>
<tr>
<th></th>
<th>New Zealand</th>
<th></th>
<th>USA</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stress</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Growth</td>
<td>°C</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>pCO₂</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Chl a</td>
<td>°C</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>pCO₂</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Cellular</td>
<td>°C</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>elements</td>
<td>pCO₂</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

- Positive
- Negative
- No effect
Discussion:

NZ clones
  • Acclimated to high $p$CO$_2$ and temperature

USA clones
  • Did not acclimate to 5°C increase
  • Temperature had greater effect than $p$CO$_2$
  • High temperature and high $p$CO$_2$ : no amplification of negative effects, in some case positive effect.

▸ Divergence: responses to temperature and CO$_2$ were different between NZ and USA cell lines.
Discussion:

Differences between USA and NZ clones potentially due to:

- Differential adaptation
- Phenotypic plasticity
Thank you for your attention

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