Physiological tipping points in a changing ocean -

*Strongylocentrotus droebachiensis*: larval development within a broad range of pCO$_2$

Narimane Dorey, Pauline Lançon, Mike Thorndyke and Sam Dupont


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Background

pH variability in the environment is big
**Background**

**pH variability** in the environment is **big**

- Daily

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*Fig. 5* Change in mean pH (±SE) of water samples from 4 habitats from the shallow back-reef at Lizard Island, together with the tidal heights (grey line). over a 48-h period. pH was sampled every 2 h. Habitats were: **a** subsurface; **b** Pocillopora damicornis; **c** D. perspicillatus algal garden; **d** open sand

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**pH variability** in the environment is **big**

- Daily
- Seasonally
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Ocean acidification

*Increased CO₂ in the atmosphere*

\[
\text{CO}_2 \rightarrow \text{H}_2\text{CO}_3 \rightarrow \text{HCO}_3^- \rightarrow \text{CO}_3^{2-} \rightarrow \text{more acidic waters (OA)}
\]

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**Fig. 5** Change in mean pH (±SE) of water samples from 4 habitats from the shallow back-reef at Lizard Island, together with the tidal heights (grey line). Over a 48-h period, pH was sampled every 2 h. Habitats were: a subsurface; b *Pocillopora damicornis*; c *D. perspicillatus* algal garden; d open sand

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**Fig. 6** Map of the modelled annual pH range simulated across the southern North Sea domain.
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- Seasonally

→ pH of 7.7 are already experienced by organisms living in coastal areas
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Thomsen et al. 2010 (Biogeosci.)
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OA will induce a shift of the pH range

Hauri et al. 2012 (Biogeosci. Discussions)
pH variability in the environment is big

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**Background**

**pH variability** in the environment is **big**

- Daily
- Seasonally

OA will induce a **shift** of the pH range

→ 1. Need to work with **broader ranges of pH**

→ 2. Need to understand the **physiology** and the **limits** of the organism, including the energetic limits

Hauri et al. 2012 (Biogeosci. Discussions)

Gullmars Fjord (1921-1987)

-0.4 pH units
Energy budgets

CO₂ induced seawater acidification impacts sea urchin larval development I: Elevated metabolic rates decrease scope for growth and induce developmental delay

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Hypothesis:

Species sensitivity
Physiological tipping point

Increased $pCO_2$

- Growth
- Maintenance
Material and methods

Study of a broad range of pH

Push the system to its limits:

→ to reveal the **tipping points** of the organism

*Strongylocentrotus droebachiensis*
Material and methods

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Push the system to its limits:
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1 month larval development

<table>
<thead>
<tr>
<th>pH</th>
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<tr>
<td>8.1</td>
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<td>7.9</td>
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<td>7.7</td>
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<td>7.5</td>
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<tr>
<td>7.3</td>
</tr>
<tr>
<td>7.1</td>
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<tr>
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Material and methods

Study of a broad range of pH

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→ to reveal the tipping points of the organism

*Strongylocentrotus droebachiensis*

1 month larval development
Growth curves by pH

Transformation: \[ \text{Size} = a + \text{Growth Rates} \times \ln(\text{Days}) \]

Slower growth at lower pH
Growth curves by pH

Transformation: Size = a + Growth Rates * ln(Days)

Slower growth at lower pH

Variability of GR between the aquaria
Growth rates as \( f(\text{average } pH) \)

Variability of GR between the aquaria \( \rightarrow \) linked to the average \( pH_T \) during the whole experiment
Growth rates as $f(\text{average pH})$

Variability of GR between the aquaria $\rightarrow$ linked to the average pH$_T$ during the whole experiment

Slower GR with decreasing pH

Developmental delay

Tipping point: mean pH$_T$ < 7.3-7.1
Health of the cultures

At pH 6.5, the eggs were alive but never divided, or divided wrongly (Pagano et al., 1985)
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Health of the cultures

Tipping point: mean pH$_T$ < 7.3-7.1

No ≠ in mortality for same-size larvae raised at pH ≥ 7.3-7.1
There are lower growth rates with lower pH but...

Is a same-size larvae morphologically the exact same larvae in a different pH condition?

Only a developmental delay?
Morphology of an average 350 μm larvae

For a same-size larvae at low pH:

- Wider body width
- Smaller arms
- Increased arm asymmetry
- Bigger stomach volume
No effect when not accounting for growth delay.
Respiration

Stumpp et al., 2011

→ increased respiration

→ increased maintenance costs
Conclusion: Energy budget of Sd larvae

Increased $p\text{CO}_2$

Slower growth rates / Higher abnormality
**Conclusion:** Energy budget of Sd larvae

- Increased $pCO_2$
- Slower growth rates / Higher abnormality
- Physiological tipping point
- Numbers:
  - 8.1
  - 7.9
  - 7.7
  - 7.5
  - 7.3
  - 7.1
  - 6.5
Conclusion: Energy budget of Sd larvae

Increased $pCO_2$

Natural range:

- 8.1
- 7.9
- 7.7
- 7.5

Increased $pCO_2$ leads to:

- Slower growth rates / Higher abnormality

Physiological tipping point:

- 7.3
- 7.1
- 6.5

The value 6.5 is marked with an X, indicating it is the physiological tipping point.
Conclusion: Energy budget of Sd larvae

2100 Natural range

8.1  7.9  7.7  7.5  7.3  7.1  6.5

Slower growth rates / Higher abnormality

Physiological tipping point

Already a mean of 7.7 is predicted to happen in scenarios for 2100
Conclusion: Energy budget of Sd larvae

Already a mean of 7.7 is predicted to happen in scenarios for 2100

Feeding disturbances // Other stressors (pollutants – temperature)
Team spring - summer 2011

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Thank you!


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