Acidification Issues in Coastal Waters of the SAML Region: Responses of Organisms

Louis E. Burnett
Grice Marine Laboratory
College of Charleston
SAML Meeting 2014

Diel cycling of hypoxia and hypercapnia

Slide borrowed from M.S. Thesis Defense of Virginia Clark
Univ. of Maryland.
Diel cycling of hypoxia and hypercapnia

Possum Point, Corsica River  St Mary's College, St. Mary’s River

Data from MD DNR’s EyesOnTheBay.net

Slide borrowed from M.S. Thesis Defense of Virginia Clark Univ. of Maryland.

Additional Water Quality Data

• National Estuarine Research Reserve System
• Centralized Data Management Office (CDMO)
• http://cdmo.baruch.sc.edu/
### Field Measurements
#### James Island Creek, SC

<table>
<thead>
<tr>
<th>Location</th>
<th>$\text{Po}_2$ (torr)</th>
<th>pH</th>
<th>Sal.</th>
<th>Temp.</th>
<th>$\text{Pco}_2$ (torr)</th>
<th>Total Alk.</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 Aug 1994 1800-1900</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Channel surface (2 cm)</td>
<td>142</td>
<td>7.64</td>
<td>5</td>
<td>32</td>
<td>2.7</td>
<td>2.67</td>
</tr>
<tr>
<td>bottom (107 cm)</td>
<td>78</td>
<td>7.48</td>
<td>13.8</td>
<td>30.5</td>
<td>2.2</td>
<td>1.86</td>
</tr>
<tr>
<td>Grass surface (2 cm)</td>
<td>133</td>
<td>7.11</td>
<td>5</td>
<td>31.5</td>
<td>10.8</td>
<td>3.06</td>
</tr>
<tr>
<td>bottom (39 cm)</td>
<td>53</td>
<td>7.28</td>
<td>11</td>
<td>30.5</td>
<td>5.3</td>
<td>2.68</td>
</tr>
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Cochran & Burnett 1996

Note: 92% air saturated

Note: 34% air saturated

Cochran & Burnett 1996

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<tr>
<td>surface (2 cm)</td>
<td>51</td>
<td>7.08</td>
<td>2</td>
<td>25</td>
<td>10.7</td>
<td>2.58</td>
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<tr>
<td>bottom (88 cm)</td>
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<td>6.48</td>
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<td>28</td>
<td>35.6</td>
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33% air saturated

46,840 µatm

13% air saturated

16,710 µatm
How do organisms respond to hypercapnia?

- Tissue pH depends upon
  - strong ion difference
  - presence of weak acids and bases
  - CO₂

- Hyercapnia generates tissue and cellular acidification.
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http://score.dnr.sc.gov/

% Survival

<table>
<thead>
<tr>
<th>Treatment</th>
<th>“Ambient” CO₂</th>
<th>0.25 torr</th>
<th>0.035 kPa</th>
<th>354 µatm</th>
</tr>
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<tbody>
<tr>
<td>hard clam</td>
<td>Mercenaria mercenaria</td>
<td>90</td>
<td>80</td>
<td>70</td>
</tr>
<tr>
<td>bay scallop</td>
<td>Argopecten irradians</td>
<td>80</td>
<td>70</td>
<td>60</td>
</tr>
<tr>
<td>Eastern oyster</td>
<td>Crassostrea virginica</td>
<td>70</td>
<td>60</td>
<td>50</td>
</tr>
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</table>

% Survival

Days

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Talmage & Gobler 2009
Treatment
"Mid" CO₂
0.49 torr
0.066 kPa
354 µatm

Treatment
"Ambient" CO₂
0.25 torr
0.035 kPa
354 µatm

% Survival

veliger
pediveliger
metamorphosed

% Survival

Days
Talmage & Gobler 2009

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Intertidal Adult Oysters

Oyster Hemolymph pH

\[
\text{CO}_2 \text{ increases to } 14 \text{ torr} = 1 \text{ kPa} = 20,000 \mu\text{atm}
\]

Case Study-Blue Crab in 1% CO\textsubscript{2}

- Cameron, J. N. 1978. J. Comp. Physiol. 123:137-141. (University of Texas at Austin, Port Aransas Marine Laboratory = Marine Science Institute)
- Exposed crabs to 1% CO\textsubscript{2}  
  = 7.5 torr = 1 kPa = 9,868 µatm
- Measured blood acid-base status with time.
Treadmill Studies

- Today Show, Segment 1: http://www.today.com/id/27906984
- Today Show, Segment 2: http://www.today.com/id/26184891/vp/18424824#27909114
- Other treadmill links, crabs and shrimp: http://burnettl.people.cofc.edu/research/treadmill.php
Shrimp on a Treadmill

Blue Crab Performance
Blue Crab Performance

Fatigue Behaviors in Blue Crabs

Stover et al. 2013
Fatigue Behaviors in Blue Crabs

Stover et al. 2013

CO₂-specific Effect

Mangum & Burnett 1986
Chronic Hypoxia Responses

- Increase concentration of respiratory pigment.
- Increase oxygen affinity of respiratory pigment.
- Blue crabs do this (deFur et al., 1990); response takes days.
  - Increase concentration of hemocyanin.
  - Increase hemocyanin oxygen affinity.

Pacific Whiteleg Shrimp

*Litopenaeus vannamei*
Pacific Whiteleg Shrimp

- Genes to make hemocyanin are turned on within 24 hours on exposure to hypoxia.
- HOWEVER, exposure to hypercapnia mutes this response to hypoxia (Rathburn et al., 2013)

References

- http://cdmo.baruch.sc.edu/
- http://mddnr.chesapeakebay.net/eyesonthebay/