Acidification and hypoxia in Jamaica Bay: Implications for bivalve populations

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Processes contributing to hypoxia also produce CO$_2$. 

Phytoplankton undergo respiration, releasing CO$_2$ and water.

$$\text{CH}_2\text{O} + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$$
Nutrient discharge into coastal zone → Nutrients stimulate algal blooms → Decay of algae = ↑CO$_2$, ↓pH, ↓DO

Invited feature

Coastal ocean acidification: The other eutrophication problem

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Effects of past, present, and future ocean carbon dioxide concentrations on the growth and survival of larval shellfish

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[Bar chart showing percent survival of Bay scallop and Hard clam at different CO2 concentrations (250, 390, 750, 1500 ppm).]
Hard clam

Low CO₂

Bay scallops

High CO₂
Cross-section of juvenile clams

Big Thick

Small Thin

390 ppm

1,500 ppm

2 week exposures

Talmage & Gobler
PNAS 2010
Hypoxia and Acidification Have Additive and Synergistic Negative Effects on the Growth, Survival, and Metamorphosis of Early Life Stage Bivalves

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Growth of juvenile hard clams (4 months old) exposed to low oxygen and acidification

Gobler et al 2014, PLOS One
Research objective

To quantify the temporal and spatial dynamics of hypoxia, acidification, and bivalve growth in Jamaica Bay.
Field surveys

- Vertical, horizontal, and time series surveys, April – November
- Continuous measurements of T, S, dissolved oxygen, in vivo fluorescence with a Sea-Bird electronics CTD.
- Total dissolved inorganic carbon (DIC) analyzed on an Environmental Gas Analyzer (EGM).
- CO₂ level calculated using CO2SYS
- Chlorophyll \(a\): 0.2\(\mu m\), 2\(\mu m\), 20\(\mu m\)
- Nutrients: ammonium, nitrate, phosphate, silicate.
Carbon dioxide and pH measurements, continuous

• Continuous, *in situ*, infrared CO$_2$ measurements made with a HydroC™ /CO$_2$ probe (Contros).

• Continuous pH measurements (total scale) made using a SeaFET with ion-selective field effect transistors.
‘Data Flow’ system

- Water intake
- Pressure valve
- Flow chamber

- YSI (Temp, Sal, DO, chla)
- Fluoroprobe (algal pigments)
- Durafet, continuous pH
- Contros, continuous pCO₂

~ 0.5 m rigid intake (RAM) ~200 gal/hr
**Day-night cycles in dissolved oxygen and pH**

<table>
<thead>
<tr>
<th>Day</th>
<th>Night</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Photosynthesis produces oxygen</strong></td>
<td><strong>No photosynthesis</strong></td>
</tr>
<tr>
<td><strong>Respiration consumes oxygen</strong></td>
<td><strong>Respiration consumes oxygen, produces CO₂</strong></td>
</tr>
<tr>
<td><strong>Oxygen, pH high</strong></td>
<td><strong>Oxygen, pH low</strong></td>
</tr>
</tbody>
</table>

**Sediment**

**Sediment**
Growth and survival experiments
Invited feature

Coastal ocean acidification: The other eutrophication problem

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**pCO₂ (µatm)**
- < 600
- 600 - 1200
- 1200 - 1800
- 1800 - 2400
- > 2400

**DO (mg L⁻¹)**
- < 3
- 3 - 4
- 4 - 5
- 5 - 6
- > 6

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**A)**

**B)**

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Kilometers
Monthly dissolved oxygen surveys, 2015

May

June

July

August

Sept

Oct

DO (mg L\(^{-1}\))

> 12

12

10

8

6

5

< 4
Monthly pCO$_2$ surveys, 2015
JFK surface waters

- General seasonal decline in DO and pH
- Bi-weekly cycles linked to algal blooms
- Large diurnal variability

NYSDEC DO standard
JFK bottom waters

- General seasonal decline in DO and pH
- Significantly lower levels of pH and DO
- Nearly three months of hypoxia according to NYSDEC standards (3 mg / L)

NYSDEC DO standard
Grassy Bay, night-to-day transition, September

- Dissolved oxygen
- pH
- $pCO_2$
- Aragonite saturation

Hours after sunset
pH and DO, Broad Channel

$R^2 = 0.71$
pH and DO, Grassy Bay

R² = 0.72
pH and DO, Grassy Bay
Three-dimensional profiling of DO in Jamaica Bay
August, 2015
Three-dimensional profiling of pH in Jamaica Bay
August, 2015
Growth and survival experiments
Growth of bivalves, June

**Eastern oysters**

- Rockaway Inlet
- Broad Channel
- JFK

**Blue mussels**

- Rockaway Inlet
- Broad Channel
- JFK
Growth of bivalves, September

**Eastern oysters**

- Rockaway Inlet: 0.030 (a)
- Broad Channel: 0.030 (b)
- JFK: 0.015 (C)

**Ribbed mussels**

- Rockaway Inlet: 0.002 (a)
- Broad Channel: 0.0015 (b)
- JFK: 0.0015 (b)
Temperature and chlorophyll $a$

**June**

- Temperature (°C) or Chlorophyll $a$ (μg/L)

**September**

- Temperature (°C) or Chlorophyll $a$ (μg/L)
Bivalve experiments, June v September

[Images showing maps of DO and pCO₂ for June and September]
Conclusions

• Jamaica Bay experiences extended periods of hypoxia and acidification during summer months.

• Growth rates of bivalves are slowed in the regions of Jamaica Bay during periods of hypoxia and acidification, even when levels of food and temperature are ideal.