Is hypoxia’s influence restricted to the deep? Evaluation of nearshore community composition in Hood Canal, Washington, a seasonally hypoxic estuary

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Is hypoxia restricted to the deep?
Spatial & temporal variation in nearshore community structure in a seasonally hypoxic estuary

Halley E. Froehlich¹, Shannon Hennessey¹, Anne H. Beaudreau¹, Timothy E. Essington¹, Phillip S. Levin²

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Salish Sea Ecosystem Conference 2014
Hypoxia

• Dissolved oxygen concentration “<2mg L\(^{-1}\)”
• Worldwide
• Pulse disturbance
• Anthropogenic

Diaz (2001); Diaz and Rosenberg (2008)
Hood Canal, Washington

Seasonal hypoxia
High productivity
Slow turnover
Deep bathymetry

Measured and Interpolated O2
August 2006 Oxygen

Newton et al. (1995)
Biological Impacts

1. Mortality

2. Sub-lethal effects
Hypoxic influence on the nearshore community?

Nearshore

- High productivity
- Nursery habitat
- Closer to human influence

Nearshore (sub-tidal)

Pycnocline

Low Dissolved Oxygen
Physiological driven patterns

Vaquer-sunyer and Duarte (2008)
Questions

1. Are there more hypoxia tolerant invertebrates and fewer fish species in the south?
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2. Does the southern community change temporally with the onset of hypoxia?
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3. Is dissolved oxygen (DO) a main predictor for species presence and absence?
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1. Are there more hypoxia tolerant invertebrates and fewer fish species in the south?

2. Does the southern community change temporally with the onset of hypoxia?

3. Is dissolved oxygen (DO) a main predictor for species presence and absence?

4. Do we detect distinct DO thresholds for ‘sensitive’ and ‘tolerant’ species?
Paired study design

- June-Sept 2010
- Depths: 10, 20, 30m
- 5min transects
- Water quality data
Water quality

Results
Results: Question 1

South composed of more hypoxia tolerant invertebrates and fewer fish species compared to the north?

**NMDS**
- Regions significantly different
- Fish associated with north

![Graph showing differences in species composition between North and South regions.](image-url)
Results: Question 1

South composed of more hypoxia tolerant invertebrates and fewer fish species compared to the north?
Southern community changes temporally with the onset of hypoxia?

**NORTH**

- 10m Sensitive
- 10m Tolerant
- 20m Sensitive
- 20m Tolerant
- 30m Sensitive
- 30m Tolerant

**Week**

- June 28
- July 12
- July 26
- Aug 9
- Aug 23

**Probability of Presence**

- 0.0
- 0.2
- 0.4
- 0.6
- 0.8
- 1.0
DO a main predictor for species presence-absence?

Rank predictor importance for each species (N=16):

<table>
<thead>
<tr>
<th>Predictor</th>
<th>No. of times</th>
<th>Mean rank</th>
<th>No. times within top 5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>rank 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depth</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Region</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temp</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sample site</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DO</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Habitat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salinity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Week</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slope</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Side</td>
<td></td>
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<td></td>
</tr>
</tbody>
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DO a main predictor for species presence-absence?

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<th>Mean rank</th>
<th>No. times within top 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth</td>
<td>6</td>
<td>3.5</td>
<td>13</td>
</tr>
<tr>
<td>Region</td>
<td>3</td>
<td>3.8</td>
<td>11</td>
</tr>
<tr>
<td>Temp</td>
<td>2</td>
<td>3.8</td>
<td>13</td>
</tr>
<tr>
<td>Sample site</td>
<td>2</td>
<td>4.9</td>
<td>9</td>
</tr>
<tr>
<td>DO</td>
<td>2</td>
<td>5.1</td>
<td>9</td>
</tr>
<tr>
<td>Habitat</td>
<td>1</td>
<td>5.9</td>
<td>8</td>
</tr>
<tr>
<td>Salinity</td>
<td>0</td>
<td>5.6</td>
<td>8</td>
</tr>
<tr>
<td>Week</td>
<td>0</td>
<td>7.1</td>
<td>5</td>
</tr>
<tr>
<td>Slope</td>
<td>0</td>
<td>7.4</td>
<td>2</td>
</tr>
<tr>
<td>Side</td>
<td>0</td>
<td>8.0</td>
<td>2</td>
</tr>
</tbody>
</table>
Detect distinct DO thresholds for ‘sensitive’ and ‘tolerant’ species?

**Broken-line analysis (GLM)**

‘Sensitive species’ (n=7)
- Breakpoint = 5.62mg L\(^{-1}\) (SE ± 0.51)

‘Tolerant species’ (n=9)
- Breakpoint = 3.77 mg L\(^{-1}\) (SE ± 0.27)
Long-term implications?

6 years of shallow, cruise data

Northwest Association of the Networked Ocean Observing Systems (NANOOS)
Hood Canal Dissolved Oxygen Program (HCDOP; http://nvs.nanoos.org/CruiseHcdop)
Summary

I. Hypoxia influencing the nearshore community
   • Synergistic/additive effects?

II. More ‘universal’ hypoxia response level (3-4 mg L\(^{-1}\))

III. More persistent low DO state in the south
    • More vulnerable? Ecosystem function?
Acknowledgements

THANK YOU:
- P. Sean McDonald
- Charles Simenstad
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- Frank Stevick
- Kelly Andrews
- Drew Froehlich
- Eric Nelson
- NOAA NWFSC
- HCDOP
- NANOOS
- Essington lab

Funding:

Sea Grant Washington
School of Aquatic and Fishery Sciences
NSF
<table>
<thead>
<tr>
<th>Common name</th>
<th>Scientific name</th>
<th>DO Range</th>
<th>DO Tolerance</th>
<th>Overall Abundance (north; south)</th>
<th>Ordination Correlation Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long-rayed star</td>
<td>Stylasterias forreri</td>
<td>0.5-6.6 ml/L</td>
<td>*more tolerant than fish &amp; crustaceans(^{14})</td>
<td>High?</td>
<td>1.3%; 3.1%</td>
</tr>
<tr>
<td>Spot prawn</td>
<td>Pandalus platyceros</td>
<td>0.9-6.9 ml/L</td>
<td>minimum lethal ~1 ml/L(^{7}); 3.5 to 4.0 mg/l (below this metabolism declines)(^{15})</td>
<td>High</td>
<td>16.2%; 15%</td>
</tr>
<tr>
<td>Squat lobster</td>
<td>Munida quadrispina</td>
<td>0.8-4.6 ml/L</td>
<td>0.1 to 0.15 ml/L, well adapted to hypoxia(^{4}); exposed to &lt; 0.5 mg/L(^{5}); no association between density &amp; DO(^{10})</td>
<td>High</td>
<td>15%; 55.1%</td>
</tr>
<tr>
<td>Dungeness crab</td>
<td>Metacarcinina/Cancer magister</td>
<td>4.9-6.6 mg/L; 2.6-7.5 ml/L</td>
<td>&gt;3.3 mg/L(^{1}); 1.2 mg/L &gt; DO &gt; 0.6 mg/L(^{2})</td>
<td>Moderate to high</td>
<td>3.2%; 3.4%</td>
</tr>
<tr>
<td>Giant California sea cucumber</td>
<td>Parastichopus californicus</td>
<td>0.32 - 6.7 ml/L</td>
<td>*more tolerant than fish &amp; crustaceans(^{14}); &gt; 3.2 mg/L; &lt; 2.5 mg/L mortality(^{16})</td>
<td>Moderate to high</td>
<td>3.1%; 4.0%</td>
</tr>
<tr>
<td>English sole</td>
<td>Parophrys vetulus</td>
<td>1.1-6.6 ml/L</td>
<td>moderate degree of hypoxia tolerance (1.09 ml/L(^{3})); condition not sig. different btw 0.4-1.0 ml/L(^{8})</td>
<td>Moderate to high</td>
<td>4.5%; 0.4%</td>
</tr>
<tr>
<td>Sunflower star</td>
<td>Pycnopodia helianthoides</td>
<td>2.6-6.8 ml/L</td>
<td>more abundant &gt;1 ml/L(^{8}); least abundant &lt; 0.5 ml/L(^{8}); &gt; 0.5 ml/L(^{13}); present in hypoxic conditions(^{13})</td>
<td>Moderate</td>
<td>9.8%; 5.3%</td>
</tr>
<tr>
<td>Shortspined sea star</td>
<td>Pisaster brevispinus</td>
<td>3.9-6.6 ml/L</td>
<td>present in hypoxic conditions(^{6}); *more tolerant than fish &amp; crustaceans(^{14})</td>
<td>Moderate</td>
<td>1.6%; 0.9%</td>
</tr>
<tr>
<td>Sculpin spp.</td>
<td>Malacocottus kincaidi; Enophrys bison</td>
<td>1.0-6.6 ml/L</td>
<td>more abundant &amp;1.3 ml/L; absent 0.6 ml/L(^{9})</td>
<td>Low to moderate</td>
<td>4.5%; 0.6%</td>
</tr>
<tr>
<td>Mottled star</td>
<td>Evasterias troschelii</td>
<td>3.0-7.3 ml/L</td>
<td>*more tolerant than fish &amp; crustaceans(^{14})</td>
<td>Low to moderate?</td>
<td>2.8%; 3.0%</td>
</tr>
<tr>
<td>Striped nudibranch</td>
<td>Armina californica</td>
<td>2.4-6.5 ml/L</td>
<td>absent ≤ 0.8 ml/L(^{8})</td>
<td>Low</td>
<td>3.6%; 0%</td>
</tr>
<tr>
<td>Pacific sanddab</td>
<td>Citharichthys sordidus</td>
<td>2.6-5.5 ml/L</td>
<td>condition sig. better in DO &gt; 1ml/L(^{8}); can move off the bottom(^{9})</td>
<td>Low</td>
<td>3.9%; 0.2%</td>
</tr>
<tr>
<td>Eelpout spp.</td>
<td>Lycodipsis pacifica</td>
<td>2.3-5.5 ml/L</td>
<td></td>
<td>Low?</td>
<td>1.2%; 0.2%</td>
</tr>
<tr>
<td>Goby spp.</td>
<td>Rhinogobiops nicholsii</td>
<td>3.3 - 6.4 ml/L</td>
<td></td>
<td>Low</td>
<td>3.1%; 0.4%</td>
</tr>
<tr>
<td>Kelp crab</td>
<td>Pugettia producta; Pugettia richii</td>
<td>6.6 ml/L</td>
<td></td>
<td>Low?</td>
<td>1.1%; 1.0%</td>
</tr>
<tr>
<td>Red rock crab</td>
<td>Cancer productus</td>
<td>3.2-6.6 ml/L</td>
<td>Emersion (&lt;12hrs)(^{11})</td>
<td>Low</td>
<td>8.2%; 1.7%</td>
</tr>
</tbody>
</table>

\(^{1}\) References: \(^{2}\) References: \(^{3}\) References: \(^{4}\) References: \(^{5}\) References: \(^{6}\) References: \(^{7}\) References: \(^{8}\) References: \(^{9}\) References: \(^{10}\) References: \(^{11}\) References: \(^{12}\) References: \(^{13}\) References: \(^{14}\) References: \(^{15}\) References: \(^{16}\) References:
<table>
<thead>
<tr>
<th>Habitat Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>cobble/sand/algae</td>
</tr>
<tr>
<td>cobble/sand/algae/seapens</td>
</tr>
<tr>
<td>cobble/sand/rock/algae</td>
</tr>
<tr>
<td>cobble/sand/rock/seawhips</td>
</tr>
<tr>
<td>cobble/sand/seawhips</td>
</tr>
<tr>
<td>cobble/sand/seawhips/algae</td>
</tr>
<tr>
<td>cobble/sand/seawhips/some algae</td>
</tr>
</tbody>
</table>