High-resolution carbonate dynamics of Netarts Bay, OR from 2014 - 2019

William Fairchild
Candidate, Masters of Science
Advisor: Dr. Burke Hales
Oregon State University
October 24, 2019
Setting

90 km south of the Columbia River mouth

Bar-built, temperate, macrotidal lagoon

12-16 perennial streams

Average depth ~3m, tide range ~2-3m

Water residence time < 12 hours, with $\frac{2}{3}$ of all water flushed during ebb tide

Extensive eelgrass beds (Zostera spp.), salt marsh covers southern extent

*McCallum (1977)*
Setting

Whiskey Creek Shellfish Hatchery

Impacted by shellfish seed crisis (2007, 2008)

Continuous monitoring efforts began in 2011

Seawater buffering + timing of intake water = larval success
Methods

**pCO2 measurements***

Rapid headspace equilibration

Gas is transported in a loop through equilibrator and a LiCOR 840

Gas detected via non-dispersive infrared absorbance

**TCO2 measurements***

Steady state, mass balance CO₂ stripping

Sample stream acidified w/ 10% HCl at 1:100 flow ratio

CO₂ gas diffuses through membrane contactor, swept away by carrier gas, detected via NDIR

Results - pCO2 variability
Results - pCO2 variability
Results - Annual variability
Results - Annual variability

Windstress data from: http://damp.coas.oregonstate.edu/windstress/
Results - Composite pCO2
Results - TCO2 measurements
Results - Annual TCO2 trends

*Windstress data from: [http://damp.coas.oregonstate.edu/windstress/](http://damp.coas.oregonstate.edu/windstress/)*
Results - TCO2 composite

- 2014 - pink
- 2015 - purple
- 2016 - blue
- 2017 - green
- 2018 - red
- 2019 - orange
Results - Alkalinity composite

- 2014 - pink
- 2015 - purple
- 2016 - blue
- 2017 - green
- 2018 - red
- 2019 - orange
Results - pH / omega composite
Results - Alk/S relationship

Alk = 474.2 + 52.172(S)

$r^2 = 0.788$, $n = 23219$
Results - Regional Alk/S relationships

- Red - Whiskey Creek
- Green - Takahashi et al., (2014)
- Orange - C. Grey et al., (2011)
- Blue - Lee et al., (2006)
### Results

Variables derived from regional North Pacific relationships

<table>
<thead>
<tr>
<th></th>
<th>Avg. offset</th>
<th>RMS offset</th>
<th>Max offset</th>
<th>Min. offset</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Alkalinity</strong></td>
<td>87.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>100.9</td>
<td>440.4</td>
<td>-187.8</td>
</tr>
<tr>
<td></td>
<td>49.2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>67.8</td>
<td>208.5</td>
<td>209.9</td>
</tr>
<tr>
<td></td>
<td>43.2&lt;sup&gt;c&lt;/sup&gt;</td>
<td>64.1</td>
<td>224.5</td>
<td>-228.9</td>
</tr>
<tr>
<td><strong>TCO2</strong></td>
<td>77.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>89.3</td>
<td>380.1</td>
<td>-64.7</td>
</tr>
<tr>
<td></td>
<td>43.4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>59.9</td>
<td>191.3</td>
<td>-184.1</td>
</tr>
<tr>
<td></td>
<td>38.1&lt;sup&gt;c&lt;/sup&gt;</td>
<td>56.7</td>
<td>208.6</td>
<td>-198.2</td>
</tr>
<tr>
<td><strong>pH&lt;sub&gt;t&lt;/sub&gt;</strong></td>
<td>0.016&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.019</td>
<td>0.098</td>
<td>-0.032</td>
</tr>
<tr>
<td></td>
<td>0.009&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.012</td>
<td>0.047</td>
<td>-0.035</td>
</tr>
<tr>
<td></td>
<td>0.008&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.012</td>
<td>0.053</td>
<td>-0.038</td>
</tr>
<tr>
<td><strong>Ω&lt;sub&gt;aragonite&lt;/sub&gt;</strong></td>
<td>0.131&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.155</td>
<td>0.305</td>
<td>-0.567</td>
</tr>
<tr>
<td></td>
<td>0.073&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.105</td>
<td>0.49</td>
<td>-0.346</td>
</tr>
<tr>
<td></td>
<td>0.066&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.099</td>
<td>0.447</td>
<td>-0.375</td>
</tr>
</tbody>
</table>

<sup>a</sup> Lee et al., (2006) - Global relationship of alkalinity and salinity with temperature in surface water of world's oceans

<sup>b</sup> C. Grey et al., (2011) - Applications of in situ pH measurements for total inorganic carbon calculations

<sup>c</sup> Takahashi et al., (2015) - Climatological distributions of pH, pCO2, alkalinity, and CaCO3 saturation in the global surface ocean, and temporal changes at selected locations
Conclusion

Netarts Bay is highly metabolic in summer

Wintertime downwelling, spring-transition, and summer upwelling dominate hydrographic regimes

Regional Alk/S models fail to capture variable freshwater end members, in-bay calcification/dissolution events, and sulfate reduction

Regional models produce varying degrees of pH and omega predictability
Check Samples

Grab samples are collected during routine maintenance and analyzed on campus.

Lab TCO$_2$ analysis on average 0.4% lower than WCSH.

Lab $p$CO$_2$ analysis on average 5% higher than WCSH.

Combined measurement uncertainty:

$p$CO$_2$: 5%

TCO$_2$: $\sim$10 $\mu$mol/kg
Results - Composite salinity

- 2014 - pink
- 2015 - purple
- 2016 - blue
- 2017 - green
- 2018 - red
- 2019 - orange
Results - Annual pH & omega variability

\[ \Omega = \frac{[Ca^{2+}] \times [CO_3^{2-}]}{K_{sp}} \]

\[ pH = -\log([H^+]) \]
$\Omega = \frac{[\text{Ca}^{2+}] \times [\text{CO}_3^{2-}]}{K'_\text{sp}}$

Results - Saturation States

Red - Whiskey Creek
Green - Takahashi et al., (2014)
Orange - C. Grey et al., (2011)
Blue - Lee et al., (2006)