Seasonal benthic metabolism on the shelf of the northern California Current System

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OCB Workshop 2019
Research Area

Physical Domain

- Eastern Boundary Current System
- Northern California Current
- Narrow Shelf <50 km wide

Highly productive ecosystems supporting major fisheries
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Highly productive ecosystems supporting major fisheries
Study Sites

- Newport Hydrographic Line
- Inner Shelf and Mid Shelf
- OOI Endurance Array
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- Newport Hydrographic Line
- Inner Shelf and Mid Shelf
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Sands
- Permeable sediments
- Subject to advective flows
- Act as filters
- Enhanced solute exchange
Hypoxia Defined
2 mg L\(^{-1}\)
1.4 ml L\(^{-1}\)
62.5 μM
60 μmol kg\(^{-1}\)

Oregon Shelf Coastal Upwelling & Oxygen

[Diagram showing Ekman transport, Inner shelf, Mid shelf, N, E, COAST, and wind arrows.]
Oregon Shelf Coastal Upwelling & Oxygen

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2 mg L⁻¹
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Pierce et al., 2012
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Oregon Shelf Coastal Upwelling & Oxygen

Source Water

Ekman transport

COAST

N

E

Inner shelf

Mid shelf

Pierce et al., 2012
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Oregon Shelf Coastal Upwelling & Oxygen

Source Water

Ekman transport

Inner shelf

Mid shelf

Hypoxia

Spring Transition

Fall Transition

\(O = 1960–1971\)
\(X = 1998–2009\)

Pierce et al., 2012

Pierce et al., 2012
Seasonal Wave Energy

July 2018

December 2018

Pressure Reduced to MSL (mb)

Pressure Reduced to MSL (mb)

Significant Wave Height (m)

Time

1/1/2018 4/1/2018 7/1/2018 10/1/2018 1/1/2019
Water Column Signatures of Seasonal Dynamics

2018-2019

WINTER (JAN)  SPRING (APR)  SUMMER (JUL)  FALL (OCT)
Effects on marine life: Dead Zones

'Dead Zone' Causing Wave Of Death Off Oregon Coast
*ScienceDaily* 14 Aug 2006

Summary of effects of reduced oxygen concentrations on marine organisms

<table>
<thead>
<tr>
<th>Type of organism</th>
<th>Effect</th>
<th>Conc. (mg L⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actively swimming fish</td>
<td>Growth</td>
<td>6</td>
</tr>
<tr>
<td>Actively swimming fish</td>
<td>Metabolism</td>
<td>4.5</td>
</tr>
<tr>
<td>Bottom-living fish</td>
<td>Metabolism</td>
<td>4</td>
</tr>
<tr>
<td>Most fishes</td>
<td>Mortality</td>
<td>2</td>
</tr>
<tr>
<td>Crabs, shrimps, lobsters, isopods</td>
<td>Growth</td>
<td>2–3.5</td>
</tr>
<tr>
<td>Bottom-living isopods</td>
<td>Mortality</td>
<td>1–1.6</td>
</tr>
<tr>
<td>Bivalve molluscs</td>
<td>Growth</td>
<td>1–1.5</td>
</tr>
<tr>
<td>Annelids</td>
<td>Growth</td>
<td>1–2</td>
</tr>
<tr>
<td>Mudskippers</td>
<td>Mortality</td>
<td>1</td>
</tr>
</tbody>
</table>

Gray *et al.* 2002

Grantham *et al.* 2004
Research Questions

1. Is there seasonal variability in benthic oxygen utilization?
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2. What is the contribution of sediment oxygen utilization to conditions of hypoxia on the Oregon Shelf?
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3. Do levels of wave energy and turbulence dictate oxygen utilization?
Research Questions

1. Is there seasonal variability in benthic oxygen utilization?

2. What is the contribution of sediment oxygen utilization to conditions of hypoxia on the Oregon Shelf?

3. Do levels of wave energy and turbulence dictate oxygen utilization?

2017-2019 Field Program
Ten cruises on R/V Oceanus
Sampling in Jan (2), Feb, Apr, May, July (2), Aug, Oct, Dec
Approach for Oregon’s Shelf

Aquatic Eddy Covariance
a water-side approach to flux measurements

\[ \overline{Flux} = \left( \overline{w'c'} \right)_h \]
Approach for Oregon’s Shelf

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Oregon Shelf Coastal Upwelling

Upwelling Indices: 45°N 125°W
Dec 2017 to Apr 2019

Data from Pacific Fisheries Environmental Lab
Oregon Shelf Coastal Upwelling

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Benthic Metabolism during Hypoxia

July 3-4 2018: Mid Shelf

Velocity (cm s⁻¹)

Pressure (m)

Time

\(O_2 (\mu M)\)
Benthic Metabolism during Hypoxia

July 3-4 2018: Mid Shelf

Current Speed (cm s⁻¹)

0 5 10
12:00 15:00 18:00 21:00 00:00 03:00 06:00 09:00 12:00 15:00 18:00

H₅₀ (m)

0 0.2 0.4 0.6
12:00 15:00 18:00 21:00 00:00 03:00 06:00 09:00 12:00 15:00 18:00

O₂ Flux (mmol m⁻² d⁻¹)

-20 -15 -10 -5 0
12:00 15:00 18:00 21:00 00:00 03:00 06:00 09:00 12:00 15:00 18:00
Benthic Metabolism during Hypoxia

Mid Shelf (80 m): Summer

$O_2$ Flux (mmol m$^{-2}$ d$^{-1}$)

July 3-5 2018
Benthic Metabolism during Hypoxia

Mid Shelf (80 m): Summer

$O_2$ Flux (mmol m$^{-2}$ d$^{-1}$)

July 3-5 2018
Seasonal Benthic Metabolism

Mid Shelf (80 m)

O$_2$ Flux (mmol m$^{-2}$ d$^{-1}$)

day of the year

Winter

Spring

Summer

Fall
Seasonal Benthic Metabolism

Mid Shelf (80 m)

Inner Shelf (30 m)
Is there seasonal variability in benthic oxygen utilization?
How do these fluxes compare?
How do these fluxes compare?

Benthic Sediment Metabolism: Oregon Shelf

\[ \text{O}_2 \text{ Flux (mmol m}^{-2} \text{ d}^{-1}) \]

- Fuchsman et al. 2015 (BC)

Depth (m)

Oregon
Washington
California

Sandy Sediments
Muddy Sediments

NH line

124°0'W
124°15'W
124°30'W
125°0'W

45°0'N
44°30'N
44°15'N
44°0'N

43°45'N

OOI

SH
How do these fluxes compare?

Benthic Sediment Metabolism: Oregon Shelf

- Fuchsman et al. 2015 (BC)
- Reimers et al. 2012 (EC)
How do these fluxes compare?

Benthic Sediment Metabolism: Oregon Shelf

- Fuchsman et al. 2015 (BC)
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- McCann-Grosvenor et al. 2014 (EC)
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Benthic Sediment Metabolism: Oregon Shelf

- $O_2$ Flux (mmol m$^{-2}$ d$^{-1}$)
- Depth (m)

- Blue circle: Fuchsman et al. 2015 (BC)
- Red square: Reimers et al. 2012 (EC)
- Green square: McCann-Grosvenor et al. 2014 (EC)
- Magenta square: Reimers et al. 2016 (EC)
How do these fluxes compare?

Benthic Sediment Metabolism: Oregon Shelf

- Winter
- Fall
- Winter

$O_2$ Flux (mmol m$^{-2}$ d$^{-1}$)

- Fuchsman et al. 2015 (BC)
- Reimers et al. 2012 (EC)
- McCann-Grosvenor et al. 2014 (EC)
- Reimers et al. 2016 (EC)
- This study (EC)
How do these fluxes compare?

Discussion Idea:
What do these fluxes indicate about organic C fluxes and retention vs. export of organic C from the shelf environment?
How do these fluxes compare?

**Summer Fluxes**
- Inner Shelf: \(-12.5\) mmol m\(^{-2}\) d\(^{-1}\)
- Mid Shelf: \(-1.8\) mmol m\(^{-2}\) d\(^{-1}\)
How do these fluxes compare?

**Summer Fluxes**
Inner Shelf: -12.5 mmol m\(^{-2}\) d\(^{-1}\)
Mid Shelf: -1.8 mmol m\(^{-2}\) d\(^{-1}\)

Water column respiration dominates (~90%) oxygen utilization on the Oregon shelf in the summer.

*From Siedlecki et al. 2015*
Do levels of wave energy and turbulence dictate oxygen utilization?

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<tr>
<td>Turbulent Kinetic Energy (TKE)</td>
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<td>Significant Wave Height ($H_{\text{sig}}$)</td>
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**Correlation coefficients for physical parameters and O₂ fluxes**
Do levels of wave energy and turbulence dictate oxygen utilization?

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Do levels of wave energy and turbulence dictate oxygen utilization?

Turbulent Kinetic Energy (TKE)  
Significant Wave Height ($H_{\text{sig}}$)  
Current Speed

**Correlation coefficients for physical parameters and $O_2$ fluxes**

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Do levels of wave energy and turbulence dictate oxygen utilization?

Turbulent Kinetic Energy (TKE)  

TKE R² = 0.79  

Current Speed  

Current Speed R² = 0.80

Significant Wave Height (Hsig)  

Hsig R² = 0.79  

OCB 2019 Summer Workshop
Summary and Implications

- Both seasonal and spatial variability in benthic metabolism on the shelf
- Highest benthic oxygen consumption in fall and winter
- Lowest sediment oxygen utilization in the summer under hypoxic conditions
- Summer fluxes compare well with model results
- Non-winter/fall fluxes compare well with previous measurements
- Strong relationships between benthic oxygen utilization and turbulent kinetic energy and significant wave height at both sites

- The margin may not be slope dominated
- Tighter coupling of carbon production and remineralization on the shelf
- Greater importance of non-summer sediment oxygen utilization