Thinking about OAD + Hypoxia

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OA = Ocean Acidification
D = Deoxygenation
Hypoxia = low oxygen stress
The California Current System

1. North Pacific Current
2. California Current
3. California Undercurrent
4. Coastal Jet
5. Freshwater influence (northern >> southern)

(right) Hewett 2020; (left) Pozo Buil et al. [2017].
The California Current System

Northern

Central

Southern

1. Salish Sea
2. Columbia River
3. Cape Blanco
4. Cape Mendocino
5. San Diego

(right) Hewett [2020]; (left) Pozo Bui et al. [2017]; USGS Woods Hole.
The California Current System

Northern
- Cape Mendocino
- Pt. Conception
- San Francisco
- San Diego

Central
- Monterey Bay
- Greater Farallones
- Bodega Head

Southern
- Columbia River
- Salish Sea

Sanctuaries
- Cordell Bank

1. Northern
2. Central
3. Southern

(right) Hewett [2020]; (left) Pozo Buil et al. [2017]; USGS Woods Hole.
Moored instrument locations

(right) modified from Hickey & Banas [2008]; Checkley & Barth [2009]
What I’m going to tell you ...

• We observed seasonal & interannual variation in upwelled water supplied to shelf
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• DO in sub-thermocline water over the shelf declines with increasing stratification → hypoxic events
What I’m going to tell you ...

• We observed seasonal & interannual variation in upwelled water supplied to shelf

• DO in sub-thermocline water over the shelf declines with increasing stratification  
  → hypoxic events

• Deoxygenation can lead to more frequent and more severe hypoxia
Upwelling favorable winds

Oxygen-poor, low pH water upwelled on to the shelf

Winds relax

Stronger vertical stratification

Net $O_2$ consumption
**Hypoxia categories & associated O$_2$ concentrations**

<table>
<thead>
<tr>
<th>Hypoxia Category</th>
<th>ml O$_2$ L$^{-1}$</th>
<th>μmol O$_2$ kg$^{-1}$</th>
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<td>Mild</td>
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<td>107</td>
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Bodega Head
Point Reyes
Farallon Islands
Cordell Bank
San Francisco Bay
Point Arena

Hypoxia categories & associated $O_2$ concentrations

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* Mild hypoxia during each deployment
* Surface (BH) & near bottom-water (all) observations: lasting hours to days
**Hypoxia categories & associated \( \text{O}_2 \) concentrations**

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*Intermediate hypoxia*

*Near bottom-water observations: lasting hours to \(~1 - 6\) day(s).*
Bodega Head
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* Short episodes of severe hypoxia in 2015
* **Near bottom-water observations**: BH (< 4 hours) & GF (~2 hours)
Temperature
Spaced @ 10m

Temperature, (Salinity), Dissolved Oxygen @ 80m (CB1) & 100m (CB2)

Cordell Bank; outer shelf moorings

Moored instruments @ CB2 & CB1

Temperature
Spaced @ 10m
lowest [DO] later than coldest water

Dissolved Oxygen (DO)

Temperature

Mooring deployment year: 2014 - 2018

mild hypoxia < 2.45 mL/L
intermediate hypoxia < 1.4 mL/L
Storm Season
December - March

Upwelling Season
April - July

Relaxation Season
August – November

CB2 DO and T
100 m depth
Cordell Bank (2014 – 2018)

Color = season

Color = [DO]

Higher spice
lower [DO]
Gulf of the Farallones; mid shelf mooring (54m)

Dissolved Oxygen

- Mild hypoxia < 2.45 mL/L
- Intermediate hypoxia < 1.4 mL/L
- Severe hypoxia < 0.5 mL/L

Alongshore wind stress (N13)

- Upwelling favorable

March 31 - June 30

Point Arena, Bodega Head, Point Reyes, Cordell Bank, Farallon Islands, N13, N26
Gulf of the Farallones; mid shelf mooring (54m)

DO declines during relaxation events

Alongshore wind stress (N13)

Dissolved Oxygen \& \(dT/dz\)

mild hypoxia < 2.45 mL/L
intermediate hypoxia < 1.4 mL/L
severe hypoxia < 0.5 mL/L

March 31 April 15 April 30 May 15 May 31 June 15 June 30

N/m²
Gulf of the Farallones; mid shelf mooring (54m)

**DO declines during relaxation events**

- **Alongshore wind stress (N13)**
- **Wind stress increasing**
- **DO increase**
- **Dissolved Oxygen & dT/dz**
- **decrease stratification**

**Legend:**
- mild hypoxia < 2.45 mL/L
- intermediate hypoxia < 1.4 mL/L
- severe hypoxia < 0.5 mL/L
Gulf of the Farallones; mid shelf mooring (54m)

Alongshore wind stress (N13)

Bodega Head
Point Reyes
Farallon Islands
Point Arena
Cordell Bank

Later in upwelling season; lower DO

Upwelling Season
April - July

mild hypoxia < 2.45 mL/L
intermediate hypoxia < 1.4 mL/L
severe hypoxia < 0.5 mL/L

Increase stratification
DO decline
Winds relaxing

Alongside upwelling favorable
Gulf of the Farallones; mid-shelf mooring

Dissolved Oxygen & $dT/dz$

Bodega Head
Point Reyes
Farallon Islands
Point Arena
Cordell Bank

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mild hypoxia < 2.45 mL/L
intermediate hypoxia < 1.4 mL/L
severe hypoxia < 0.5 mL/L

Lowest [DO] during relaxation events
Increase stratification
[DO] decline
Winds relaxing
upwelling favorable
Later in the season; lower [DO]
Gulf of the Farallones; mid shelf mooring

Dissolved Oxygen & $\frac{dT}{dz}$

mL/L

N/m^2

Alongshore wind stress (N13)

Bodega Head

Point Reyes

Farallon Islands

Point Arena

Cordell Bank

Lowest [DO] during relaxation events

Increase stratification

[DO] decline

Winds relaxing

upwelling favorable

Later in the season; lower [DO]

Decreasing wind stress

Increase stratification

[DO] decline

upwelling favorable

N/m^2

$\frac{dT}{dz}$ °C/m

mild hypoxia < 2.45 mL/L

intermediate hypoxia < 1.4 mL/L

severe hypoxia < 0.5 mL/L
Gulf of the Farallones; mid shelf mooring

Alongshore wind stress (N13)

- Dissolved Oxygen & $\frac{dT}{dz}$ (mL/L)
- $\frac{N}{m^2}$

- Bodega Head
- Point Reyes
- Farallon Islands
- Point Arena
- Cordell Bank

- Mild hypoxia: $< 2.45$ mL/L
- Intermediate hypoxia: $< 1.4$ mL/L
- Severe hypoxia: $< 0.5$ mL/L

- Lowest [DO] during relaxation events
- Increase stratification

- DO increase
- Winds relaxing; upwelling favorable, later in the season; lower DO with increasing wind stress; upwelling favorable

- DO $[mL/L]$ vs. $\frac{dT}{dz}$, °C/m