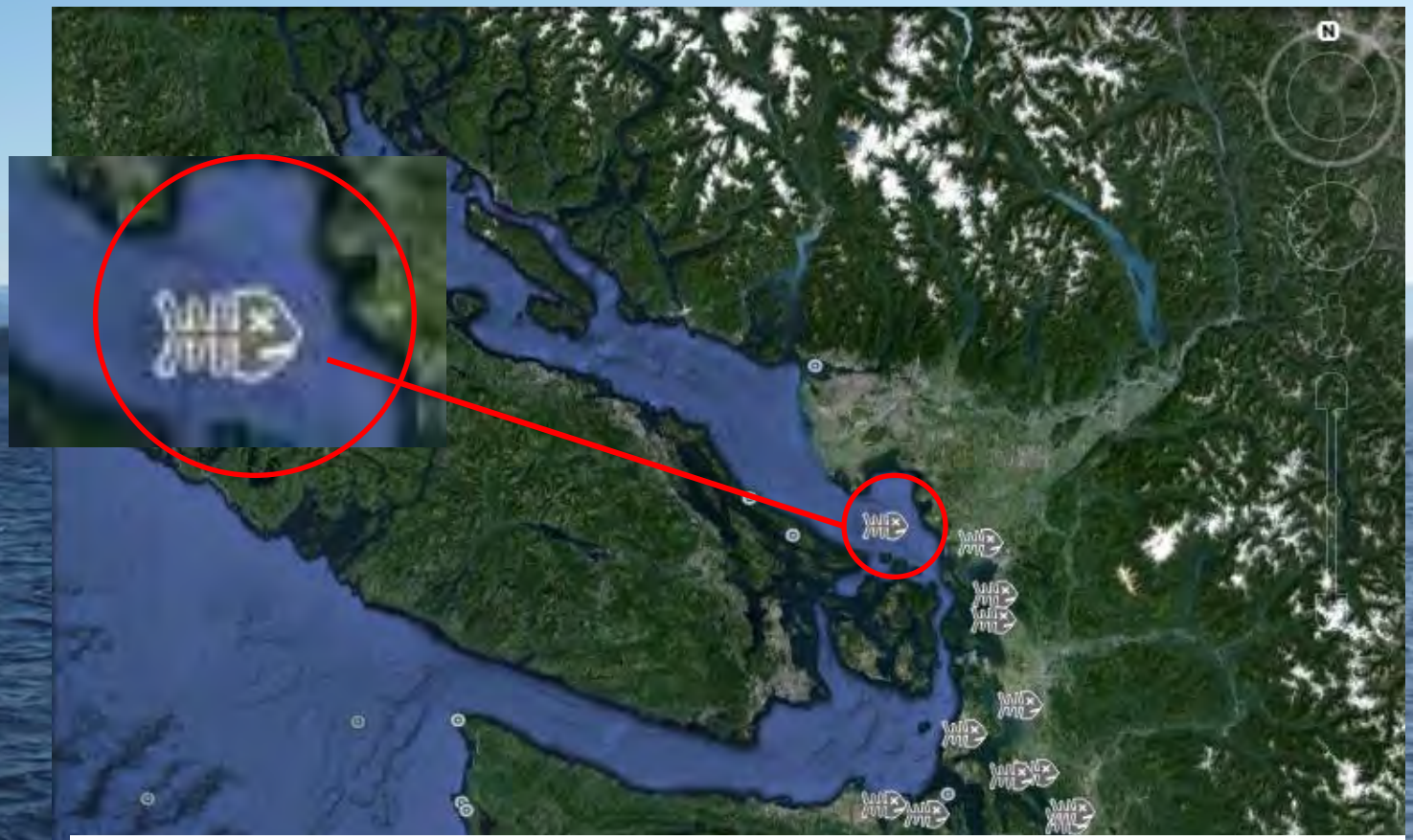
Why the Strait of Georgia is not a Dead Zone

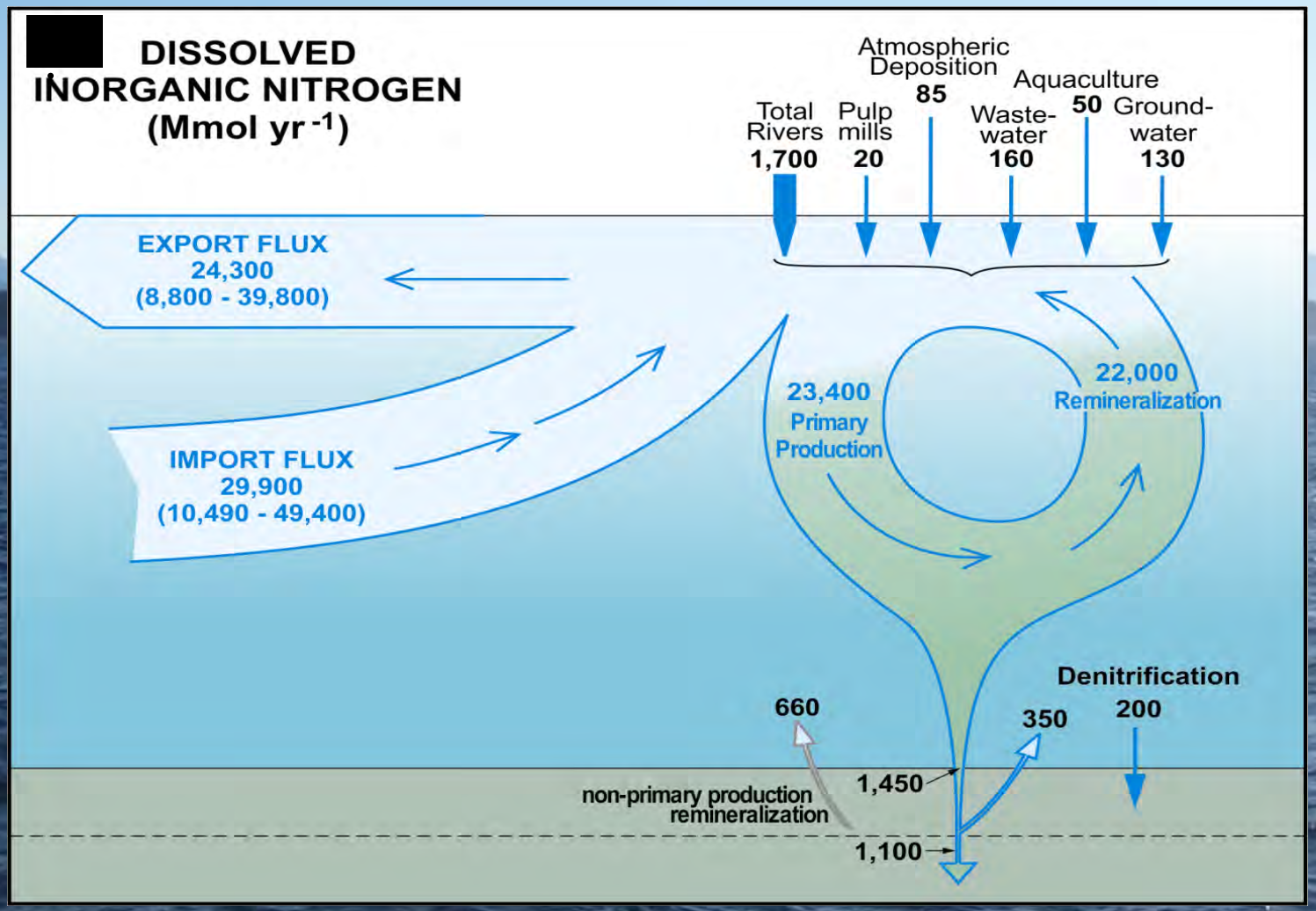
Sophie Johannessen, Diane Masson and Rob Macdonald
DFO Institute of Ocean Sciences, Sidney, B.C.

Google Earth has awarded the Strait of Georgia a dead fish.

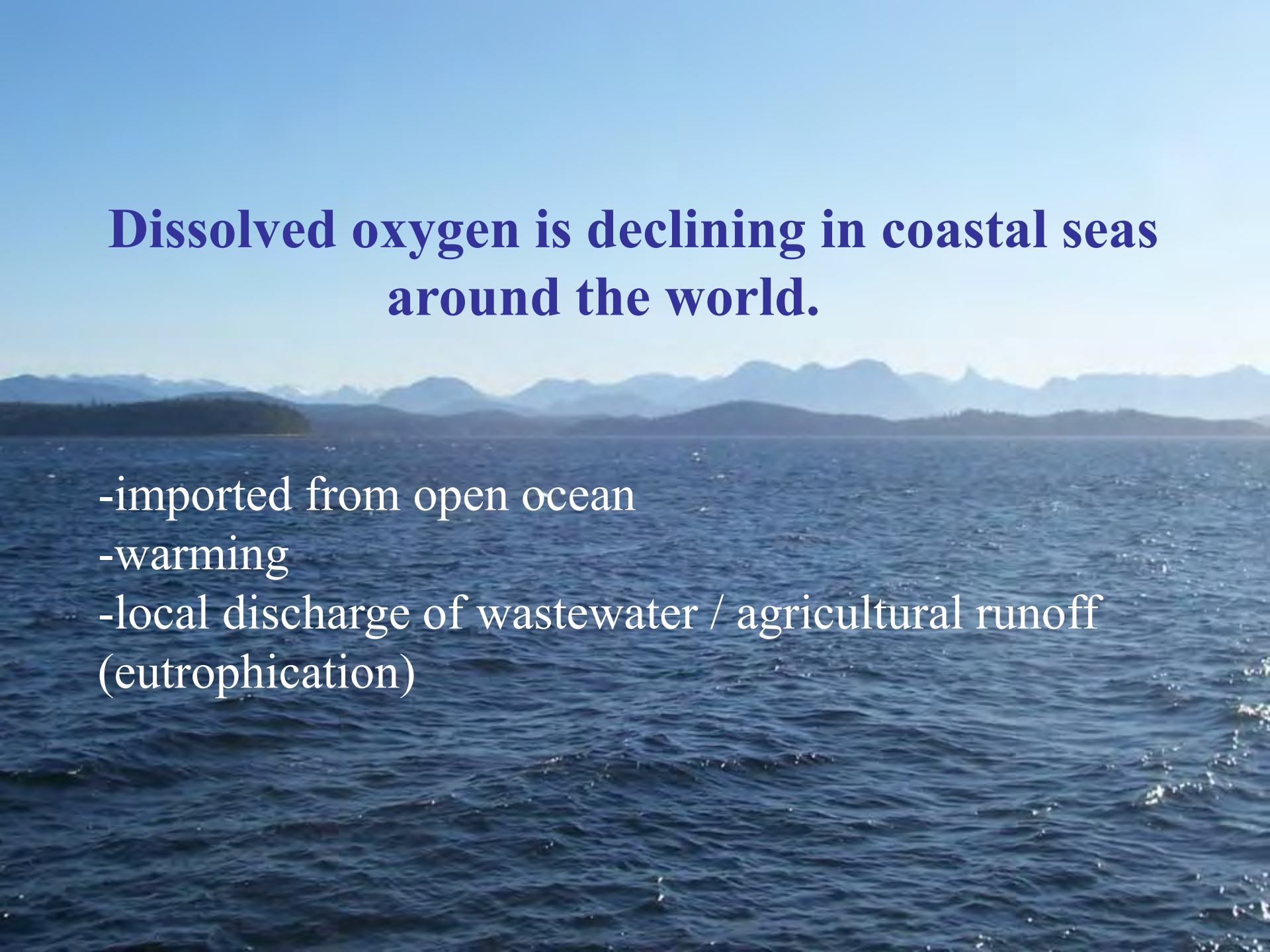


Based on Diaz classification:
Eutrophic, hypoxic, dead zone
http://www.vims.edu/research/topics/dead_zones/

Nutrient concentrations are high in the Strait, but not due to local human activities



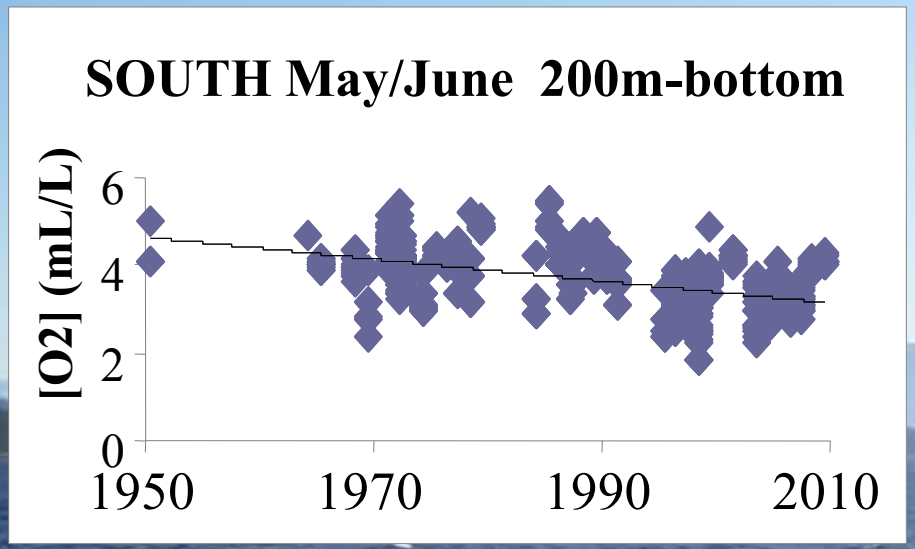
Sutton et al., in press, Biogeosciences

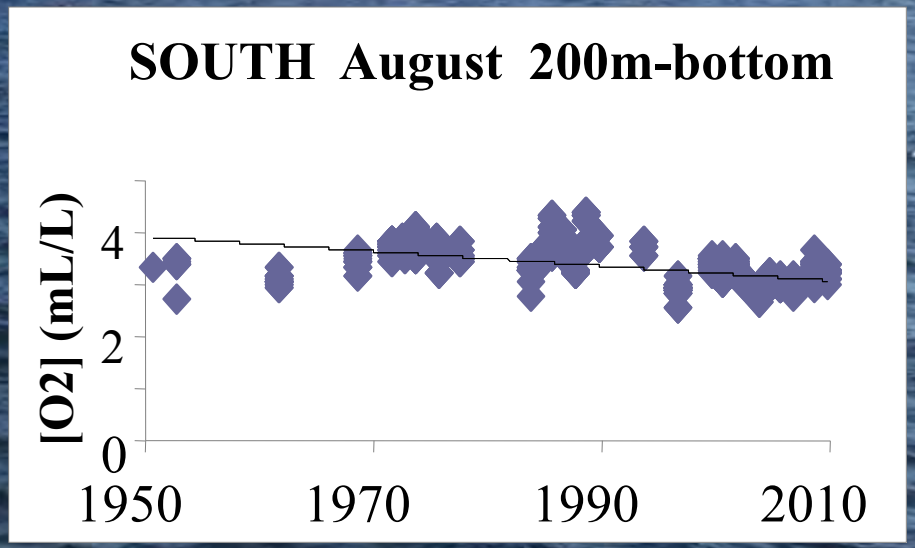


Dissolved oxygen is declining in coastal seas around the world.

-imported from open ocean
-warming
-local discharge of wastewater / agricultural runoff (eutrophication)

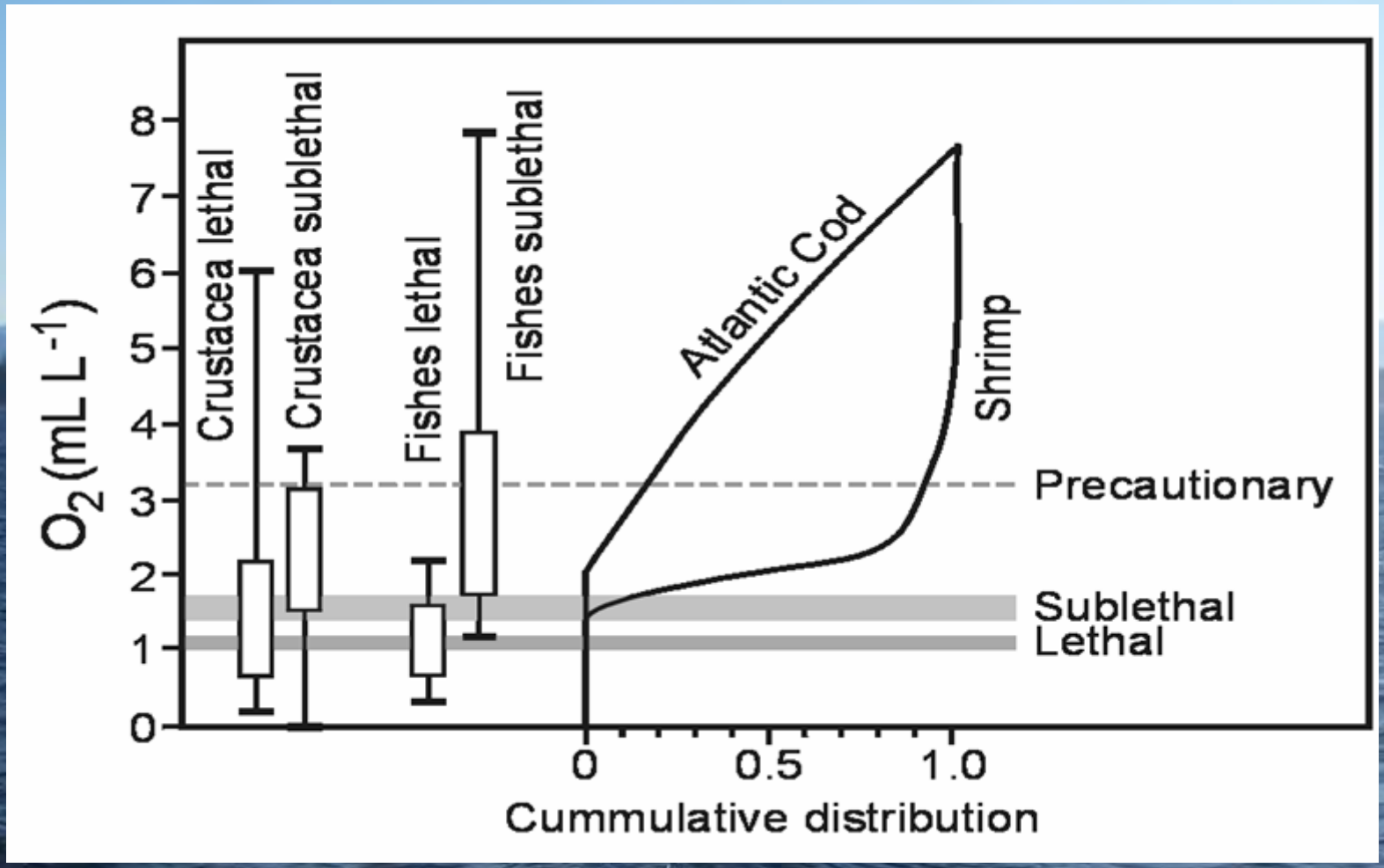
O_2 has declined in the Strait of Georgia since the 1970s.





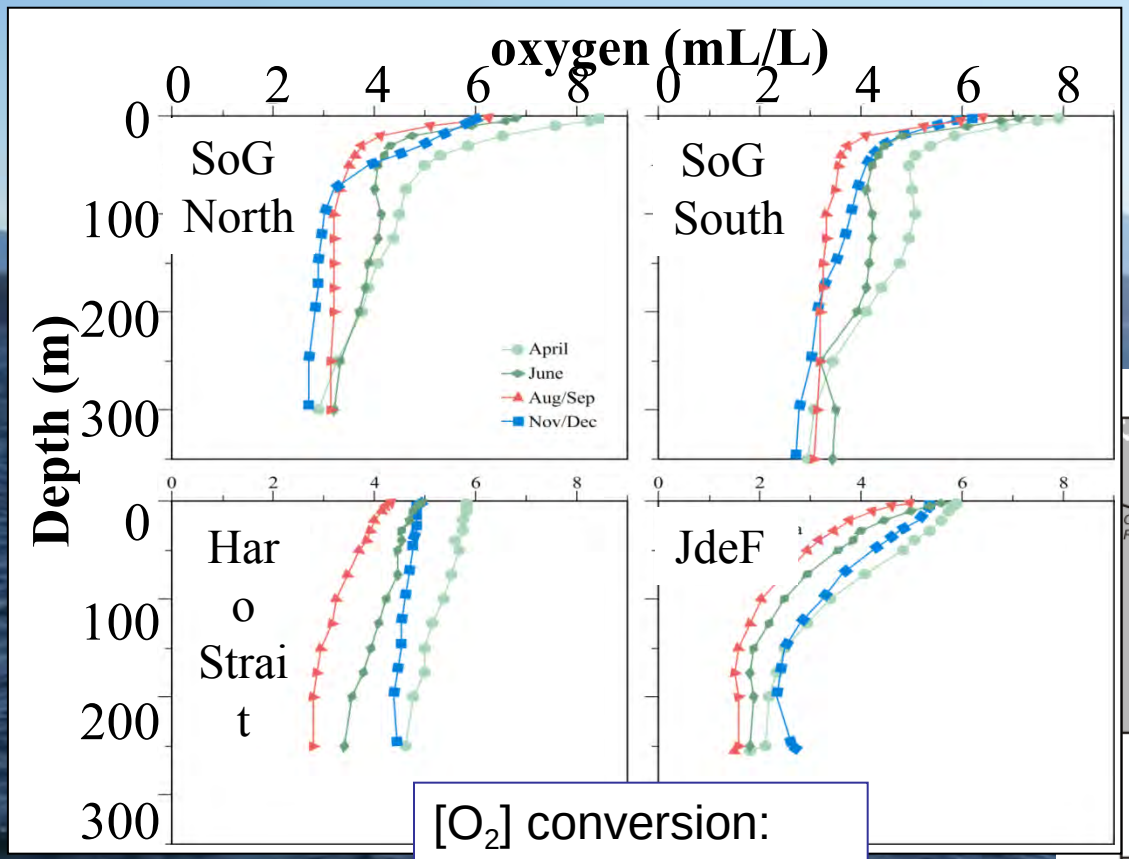
Oxygen was sometimes lower 1951-1970 than in 1980s

Thresholds of Tolerance

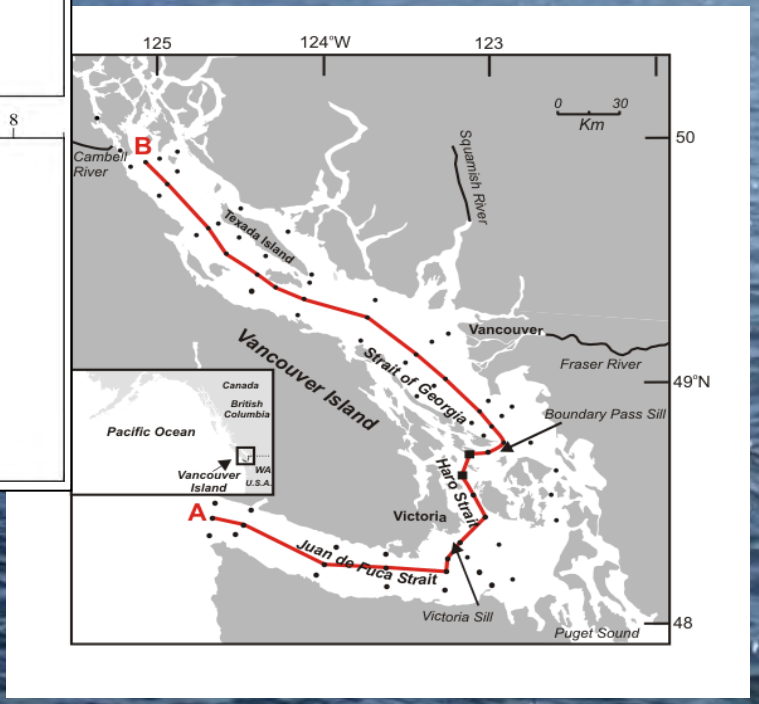


Johannessen & Macdonald, 2009, Climate Research
Adapted from: Vaquer-Sunyer & Duarte 2008. PNAS and Gilbert et al. 2007 le Naturaliste Canadien

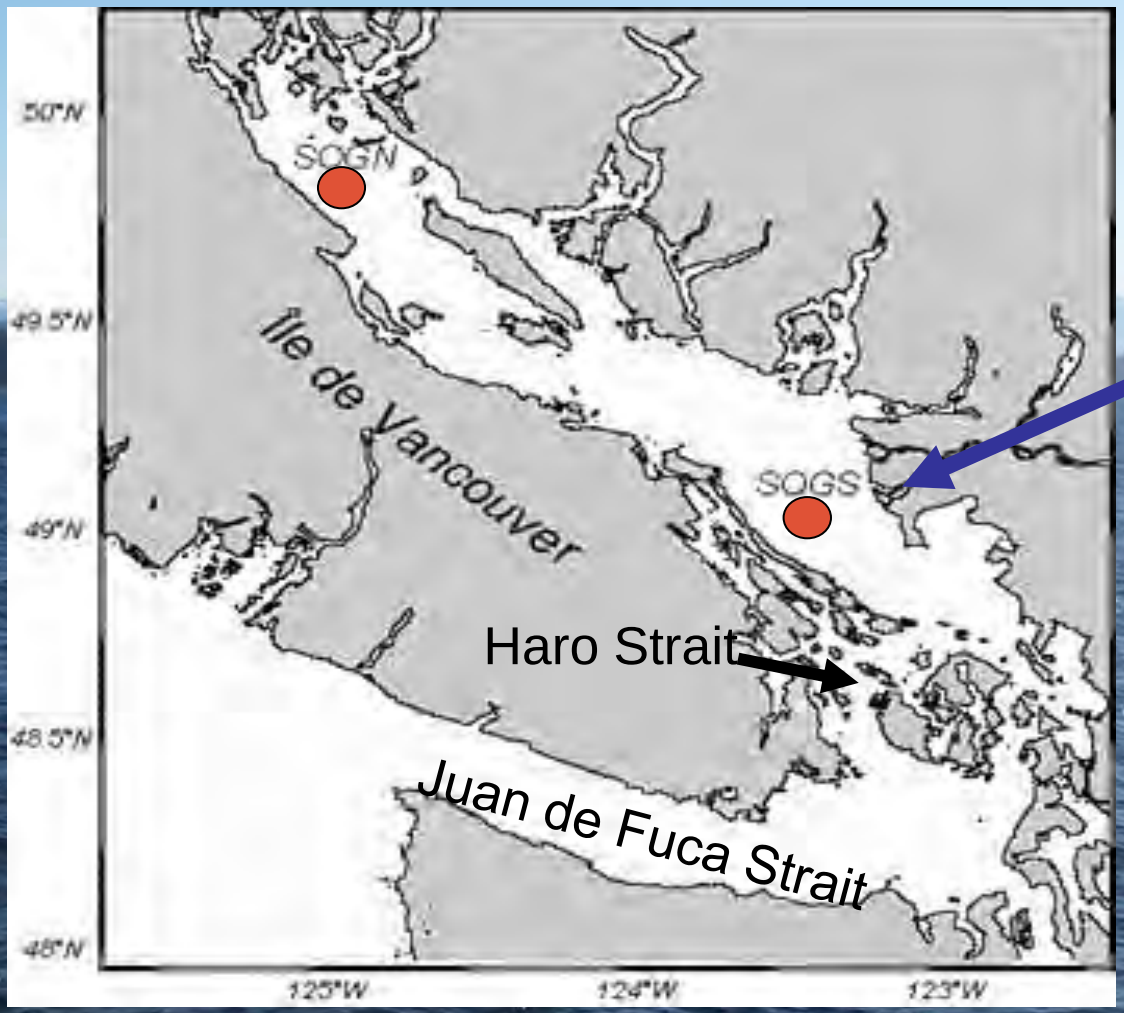
Seasonal oxygen profiles (2001-2009)
Deep Juan de Fuca Strait hypoxic seasonally
Deep SoG approaches hypoxia



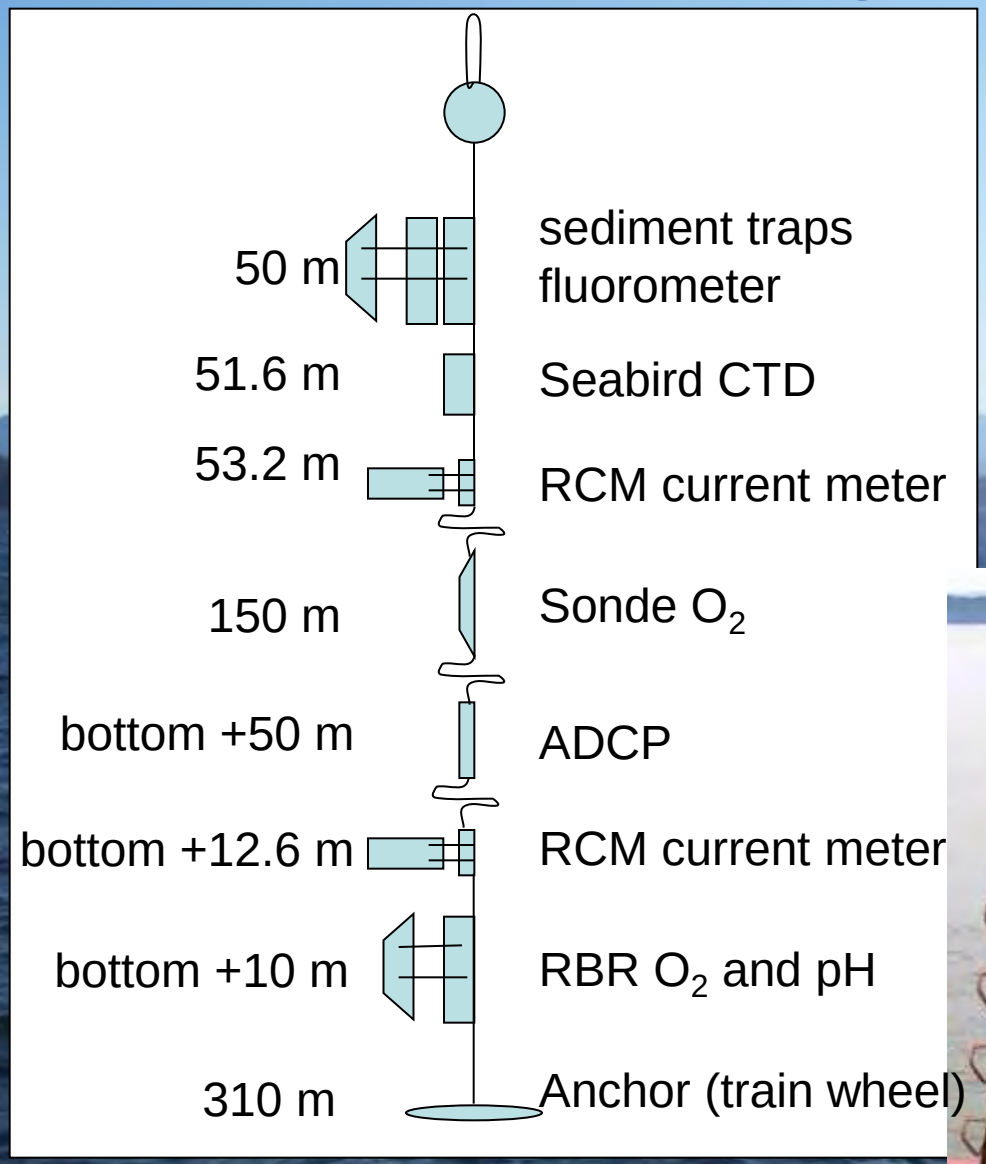
[O_2] conversion:
1 mL/L = 45 μmol/L



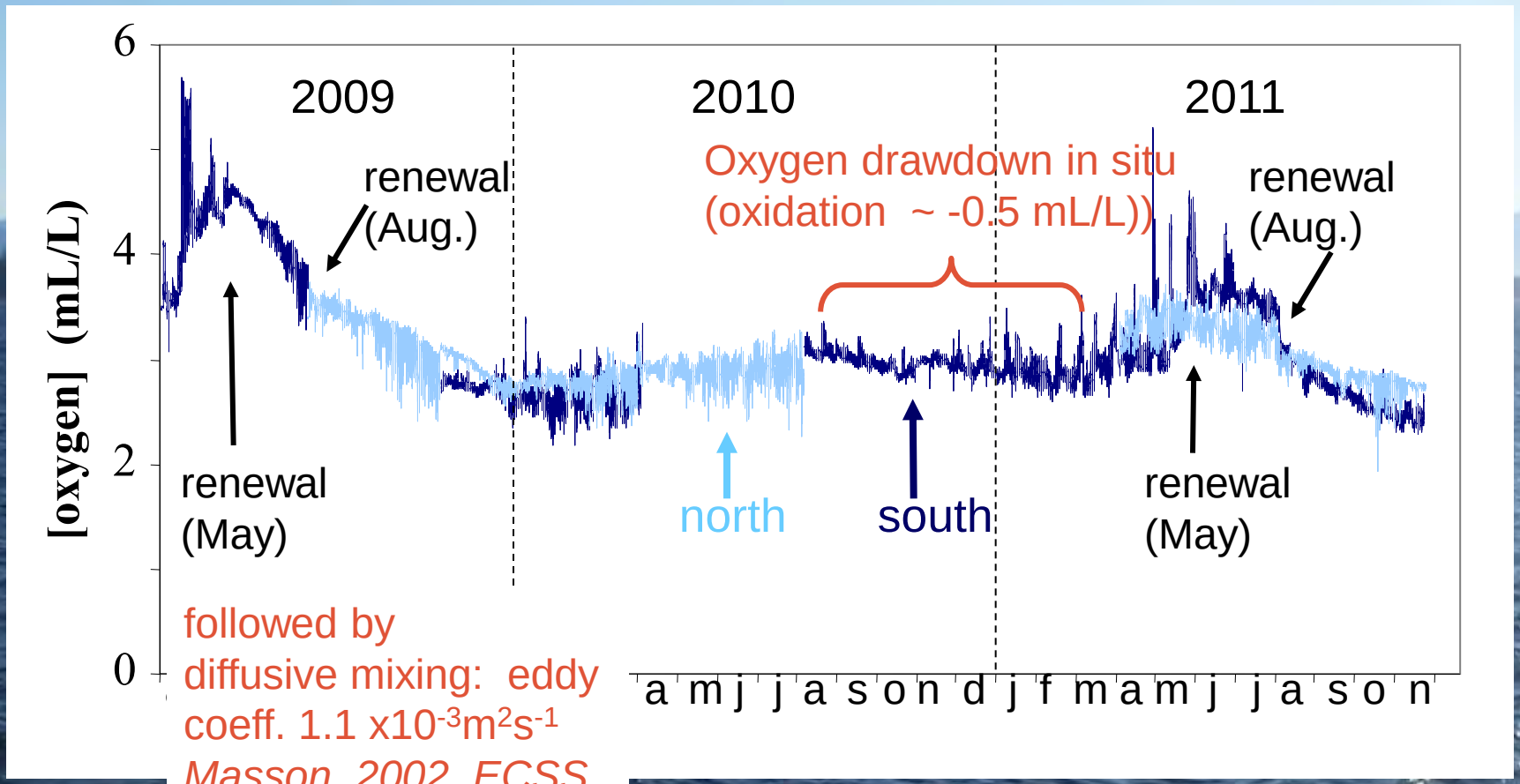
Assess seasonal and short-term variability in oxygen Using moorings



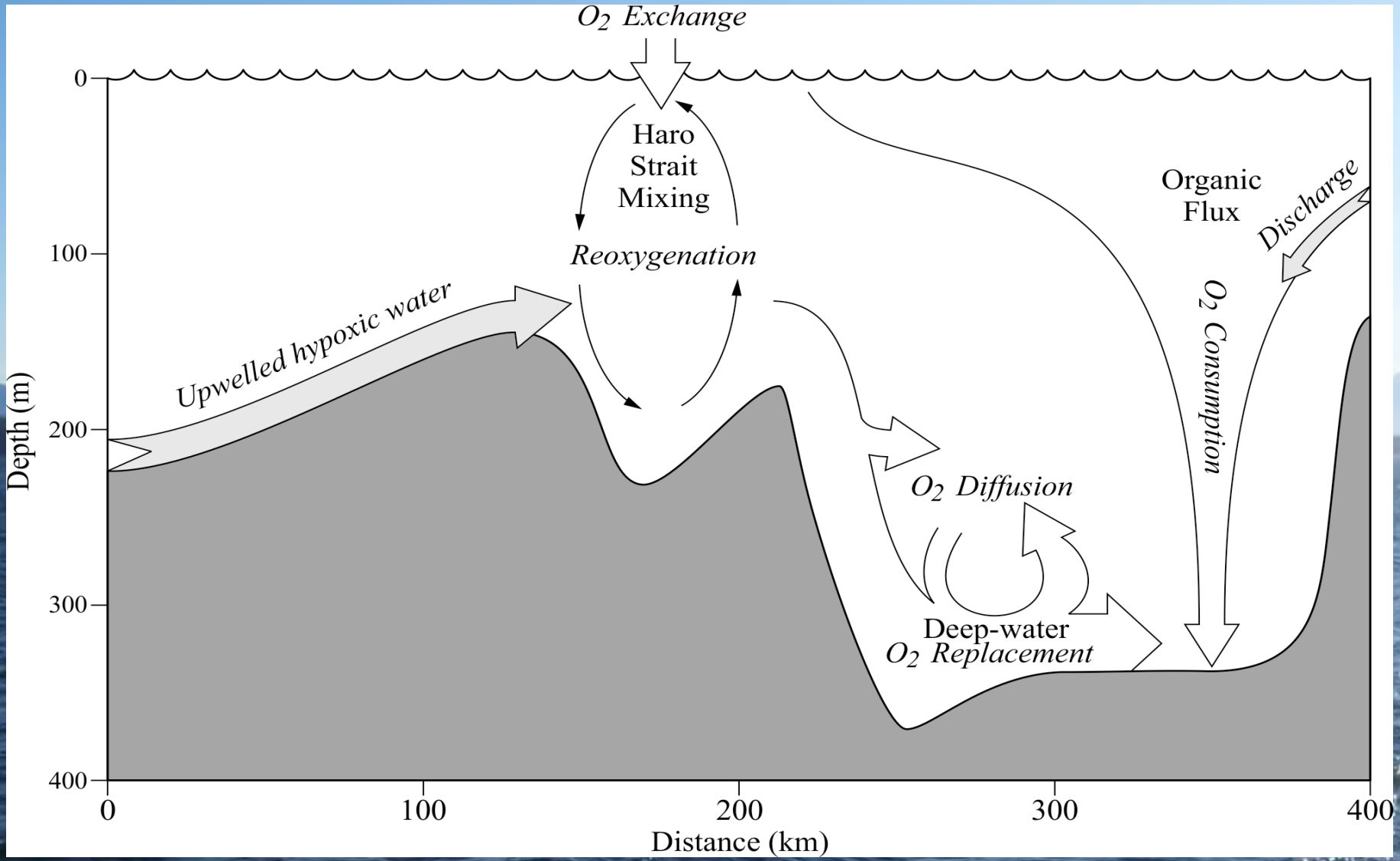
Moorings 2008-2012



The concentration of oxygen at 300m at the northern and southern moorings, April 2009 – November 2011



Johannessen et al., in press, Limnology and Oceanography



Why the Strait of Georgia is different from the Gulf of Mexico…

Johannessen et al., in press, Limnology and Oceanography

Figure 8

Possible explanations for O_2 decline

Increased O_2 Drawdown within the Strait of Georgia

Higher influx from coast due to wastewater, pulp mills etc.

Higher Productivity (respiration)

Higher proportion fluxes to bottom (grazing mismatch)

Enhanced O_2 drawdown at bottom of SofG because of warming/microbial activity (benthic demand)

Decreased O_2 in incoming water

Increased T

Decreased mixing in Haro Strait

O_2 decline in upwelled source water

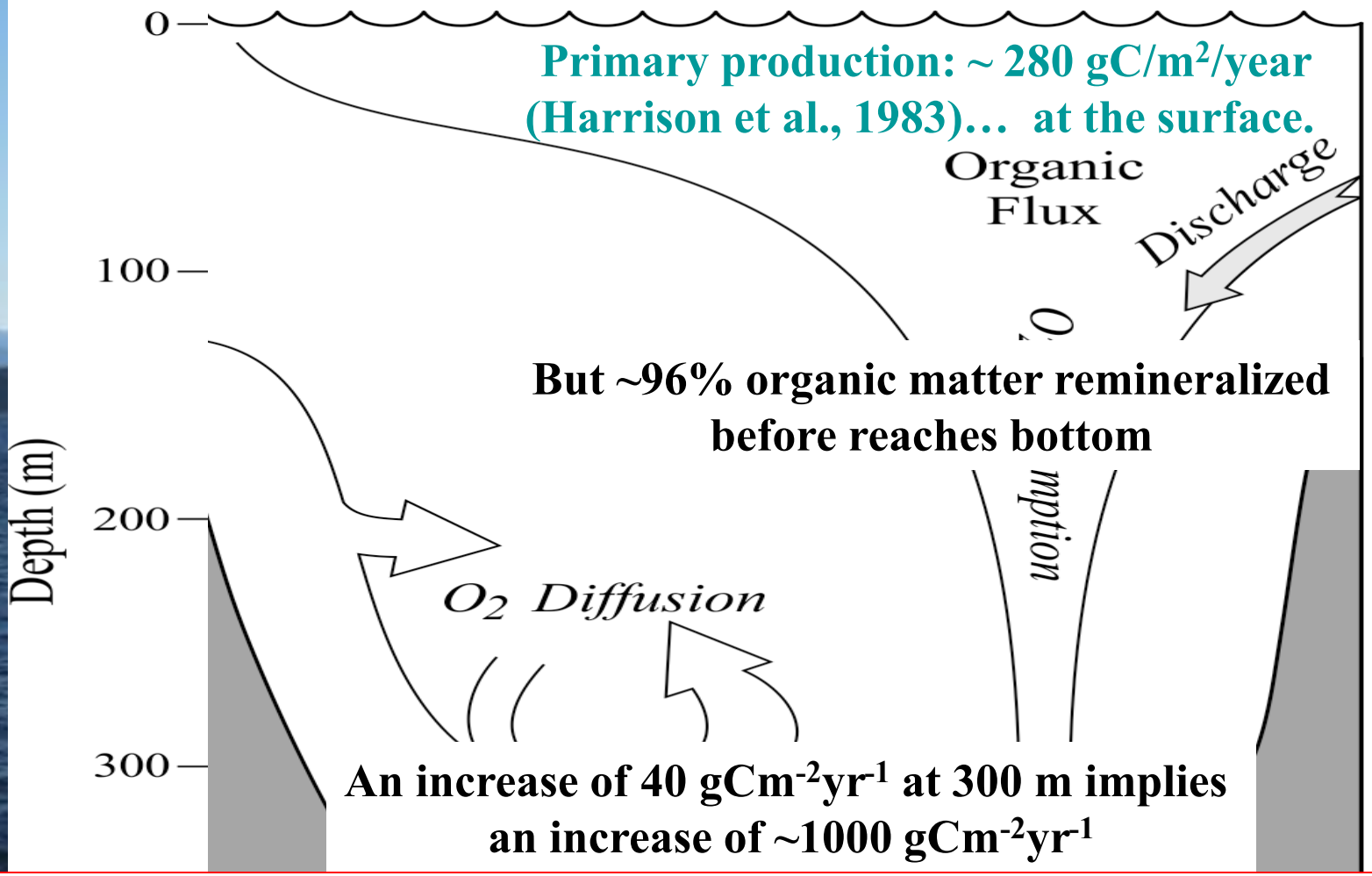
Is the flux of organic C into the Strait increasing?

An increase of about 40g C/m^2/year required over 40 years at 200m depth

- **Municipal wastewater: ~2 gC/m^2/year total… at the surface**
- **Pulp mills reduced biochemical O_2 demand by 88% over 1990s**

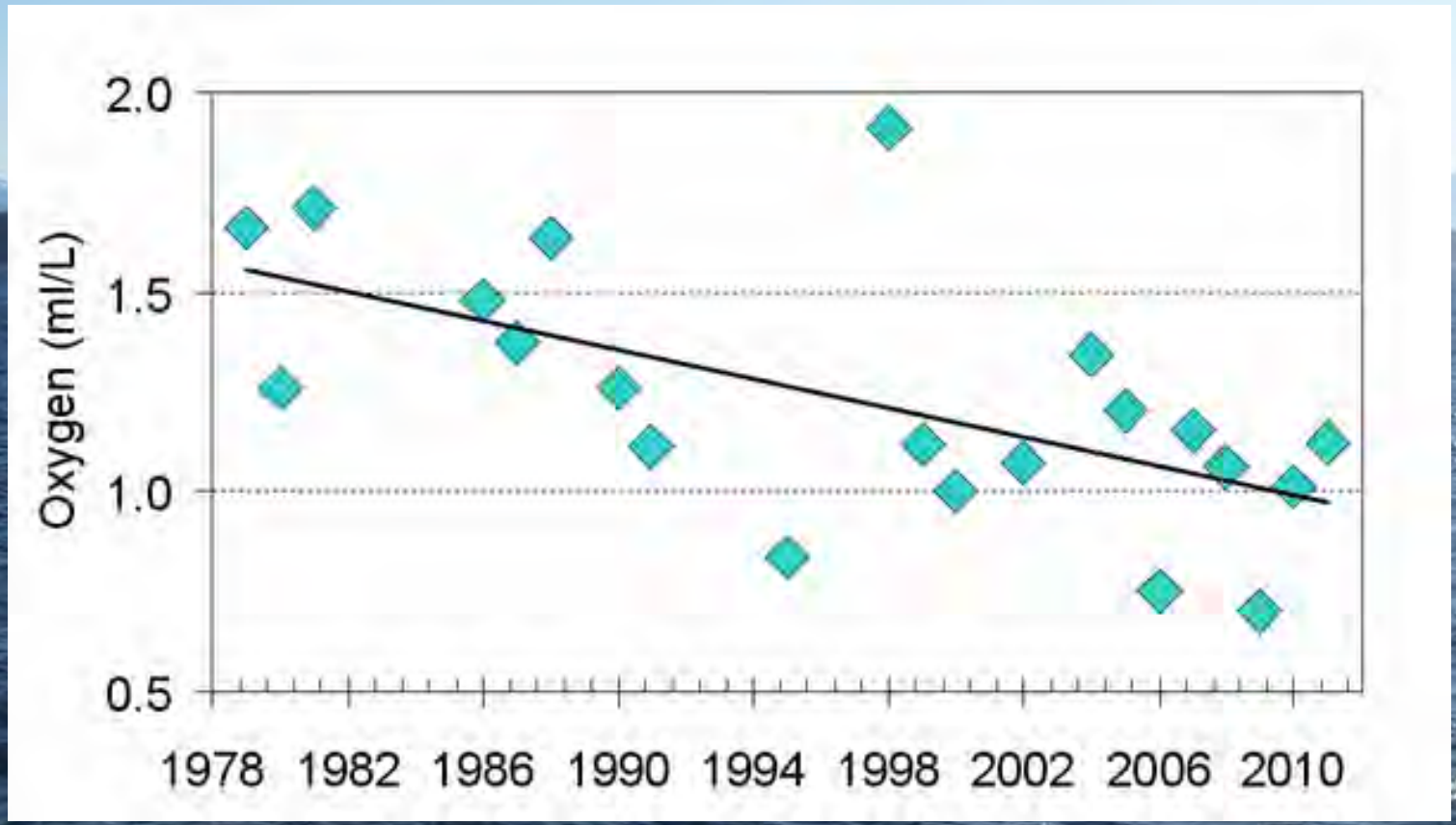
Increased organic C flux from local discharges cannot explain the decline in O_2.

Primary production and remineralization



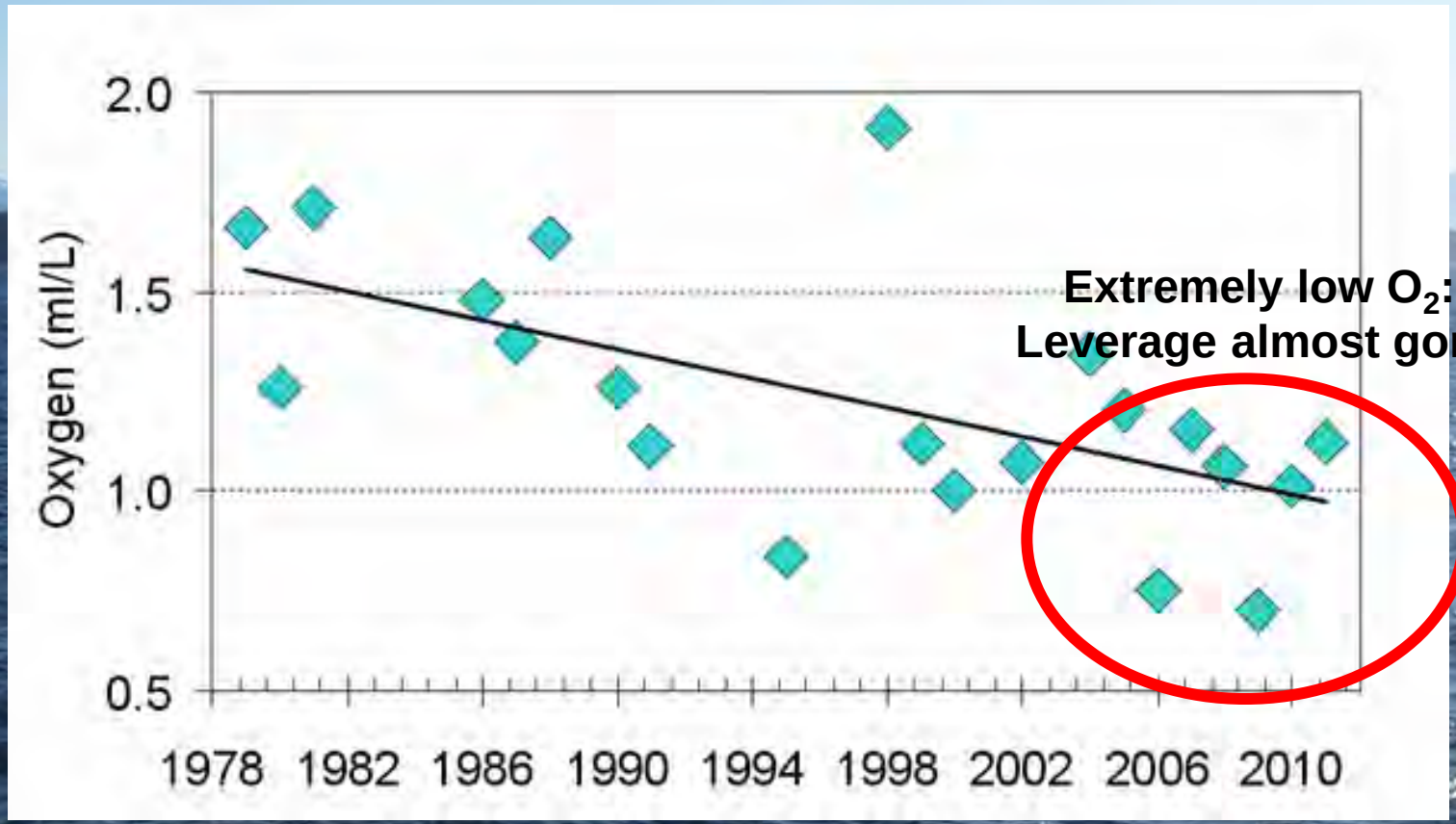
Increased primary production inside the Strait of Georgia cannot explain the decline in O_2.

The concentration of oxygen in upwelled water at 125 m at the mouth of Juan de Fuca Strait (in summer) has decreased at 0.02 mL/L / year since 1978.



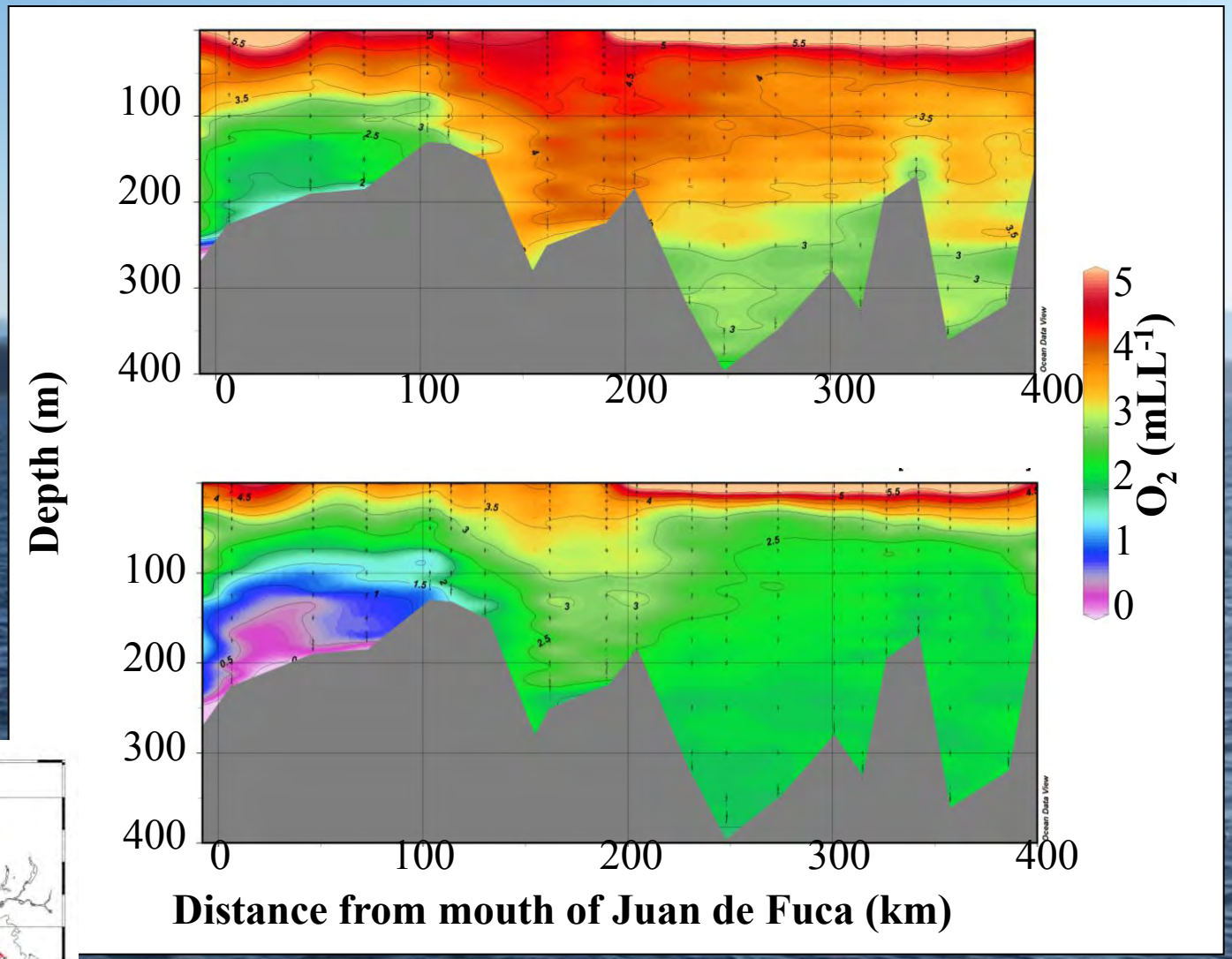
Crawford & Peña, 2013 Atmosphere-Ocean.

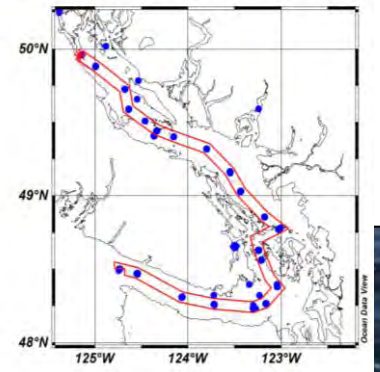
The concentration of oxygen in upwelled water at 125 m at the mouth of Juan de Fuca Strait (in summer)



Crawford & Peña, 2013 Atmosphere-Ocean.

Model: Anoxic Juan de Fuca inflow would reduce deep SoG O_2 to ~ 2 mL/L





Johannessen, Masson and Macdonald, submitted

Figure 2

Conclusions

1. Deep-water renewal, tidal mixing and diffusion largely govern the concentration of oxygen in the deep Strait. (balance with remineralization)

2. Dissolved oxygen is declining in the deep Strait of Georgia, due to decline in upwelled source water, and is approaching biological tolerance thresholds.

3. Even if source water becomes anoxic, the deep Strait of Georgia likely will not because of mixing in Haro Strait.

The Strait of Georgia is not a Dead Zone and is unlikely to become one.

Acknowledgements

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