Ocean Acidification: \( \text{CO}_2 \text{ in the the Salish Sea and Burrard Inlet} \)

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photo courtesy Sally Leys, University of Alberta
We know about 10 Gt Carbon/yr about 2% increase every year atmospheric PCO2 increase about 2 uatm/yr

https://scripps.ucsd.edu/programs/keelingcurve/
we know:

the ocean takes up about 1/3 of this anthropogenic CO2 uptake causes acidity in the ocean to increase
we also know:

- local effects can increase acidity
- organic carbon decays into CO₂
  - sewage adds organic carbon
  - agricultural runoff stimulates production of organic carbon
Shellfish are well relatively well studied - shells dissolve when the water gets more acidic - juveniles can’t survive

- likely bad
- likely neutral
- likely good
- unknown
- maybe bad low certainty

Economics

10 million$ (landed value)
Cultural impacts of Ocean Acidification

Shellfish are well relatively - shells dissolve when the water gets more acidic - juveniles can’t survive.

Clams

Clam Gardens project (CBC news January 2017)

Haigh et al. 2015 PLOS ONE
Where is carbon stored in the ocean?

Salt
- saltier water is more dense
- in BC lots of fresh water enters surface

e.g. in Strait of Georgia (SoG)
Where is carbon stored in the ocean?

More carbon in deeper water

Ianson et al. *GRL* 2016
Where is carbon stored in the ocean?

250 m

more carbon in deeper water

Pacific deep water is old - has lots of carbon

Ianson et al. GRL 2016

Carbon (DIC)

(1) like S - dilution + circulation physics

(2) organic rain decays and adds CO2 biology
comparing SoG to west Vancouver Island

- pH is variable - circulation important - pH in SoG is low

Depth zone (m) Description
0–20 Surface mixed layer
0–50 Pelagic zone
50–125 Shallow banks
125–200 Sand/mud flats
200–330 Shelf break
330–500 Slope
500–800 Oxygen minimum
800–1200 Lower slope
1200–1600 Canyon floor

$P_{\text{CO}_2}$ ($\mu$atm)
0 400 800 1200 1600
7.4 7.6 7.8 8.0 8.2 8.4

pH
Depth zone (m)

Example organisms
- Phytoplankton, Geoduck, Sea Urchins
- Macroalgae, Zooplankton, Crabs, Sockeye Salmon
- Sardines, Prawns, Pacific Herring
- Pacific Cod, Pacific Hake, Pacific Halibut, Sole
- Pacific Ocean Perch, Sablefish
- Rougheye Rockfish
- Shortspine Thornyhead, Dover Sole
- Longspine Thornyhead
- Brittle Star, Grenadier

Based on Haigh et al. 2015
comparing SoG to west Vancouver Island

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$P_{\text{CO}_2}$ (µatm) pH

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present-day atmospheric $P_{\text{CO}_2}$

present-day global average surface pH

hard to see Ocean Acidification trend

based on Haigh et al. 2015

10 years wide!
Strait of Georgia model pH

Moore-Maley et al. *JGR* 2016

strong seasonal variability
large differences between years (Fraser River)
Surface water flows out
Ocean water flows in underneath
DIC = dissolved inorganic carbon

DIC (umol/kg)

pH

O₂ (umol/kg)

TA = total alkalinity

TA (umol/kg)

Juan de Fuca - Ocean

S - PSS78
**Strait of Georgia** has more Carbon (DIC)

pH is much lower in the SoG

- no regional TA variation
- Fraser basin - carbonate

**deep water intrusion**
July 2012
Circulation - Indian Arm

Surface water flows out
SoG water flows in underneath
same data
- stars for newer 2018 data
- expanded Salt axis, fresher
Indian Arm has even more DIC than the SoG low pH in the deep basin! long residence time
Summary

The Pacific region has high carbon and low pH

The Strait of Georgia and inlets like Indian Arm have distinct chemistry and shockingly low pH

Deeper waters have lower pH

Surface waters have strong seasonal variability

We don’t know how much pH has changed in time

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photo courtesy Nina Nemcek, IOS-DFO
Indian Arm is physically unique
strong warm subsurface signature
carbon chemistry in saltwater

- pCO₂
- total inorganic CO₂ (DIC)
- alkalinity
- pH

\[ \Omega = \left[ \text{Ca}^{2+} \right] \left[ \text{CO}_3^{2-} \right] / K_{sp} \]

need to know at least 2 to pin down the others

independent of the cocktail

depend on the cocktail

\( \Omega < 1 \), dissolution

Ω = 1 horizon

snow line

photo: Moira Galbriath
farmed Atlantic Salmon dominate landed values

— highly susceptible to *Heterosigma akashiwo*, harmful algae that destroy gills.
— *H. akashiwo* blooms are expected to increase with increased carbon

OA will (may?) not to be kind to aquaculture