Assessing Vulnerability to Ocean Acidification in the Strait of Georgia Along the Canadian Pacific Coast

MEOPAR

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SFU SIMON FRASER UNIVERSITY ENGAGING THE WORLD

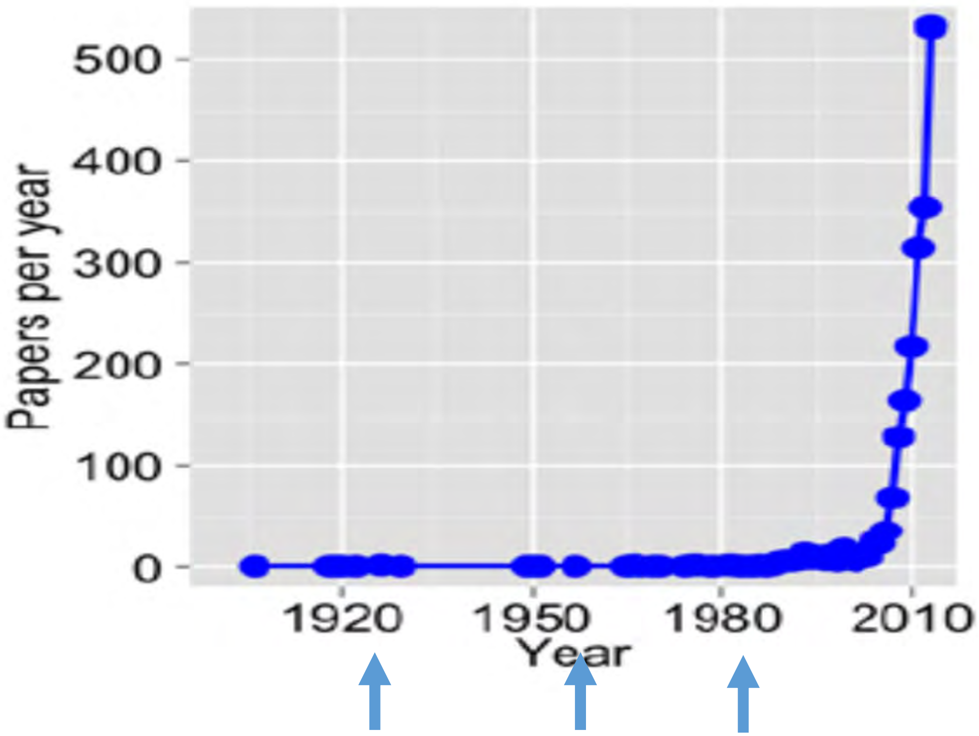
Fisheries and Oceans Canada

UBC THE UNIVERSITY OF BRITISH COLUMBIA

ETH zürich

[5]Little Wing Oysters, Ltd
[6]Okeover Organic Oysters
[7]Stellar Bay Shellfish, Ltd
[8]Salty Dogs Seafoods

Historical awareness of Ocean Acidification



Redfield and Goodkind (1929)
CO2 exposure impacts

Revelle (1957)
CO2 uptake by
oceans

Feely et al. 1984
Effect on saturation state

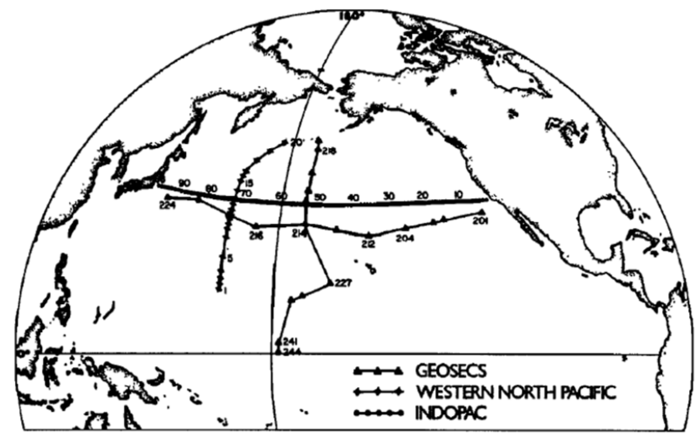
Secretariat of the Convention on Biological Diversity (2014)

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 89, NO. C6, PAGES 10,631–10,640, NOVEMBER 20, 1984

Factors Influencing the Degree of Saturation of the Surface and Intermediate Waters of the North Pacific Ocean With Respect to Aragonite

RICHARD A. FEELY,[1] ROBERT H. BYRNE,[2] PETER R. BETZER,[2] JAMES F. GENDRON,[1] AND JAMES G. ACKER[2]

New carbonate chemistry data obtained during a 1982 cruise have been combined with earlier GEOSECS and INDOPAC data to determine the degree of aragonite saturation of surface and intermediate waters of the North Pacific. Large gradients in saturation state occur in the region of the Subarctic Front in the north-south direction and across the Subtropical Gyre in the east-west direction. These gradients are primarily due to the extensive mixing that occurs in the intermediate waters of the western North Pacific. The major variations in saturation state were primarily related to the carbonate ion concentration, which, in turn, is primarily a function of mixing and biological processes. The present aragonite saturation depth at our northernmost station in the western North Pacific was calculated to be within 120 m of the surface. This result was directly corroborated by observations of aragonite dissolution under in vitro conditions. Our calculations show that one possible effect of fossil fuel–derived CO_2 on the surface of the North Pacific will be a steady progression of undersaturation from the northern to southern and western areas, with the first sign of undersaturation possibly occurring as early as the second half of the next century.



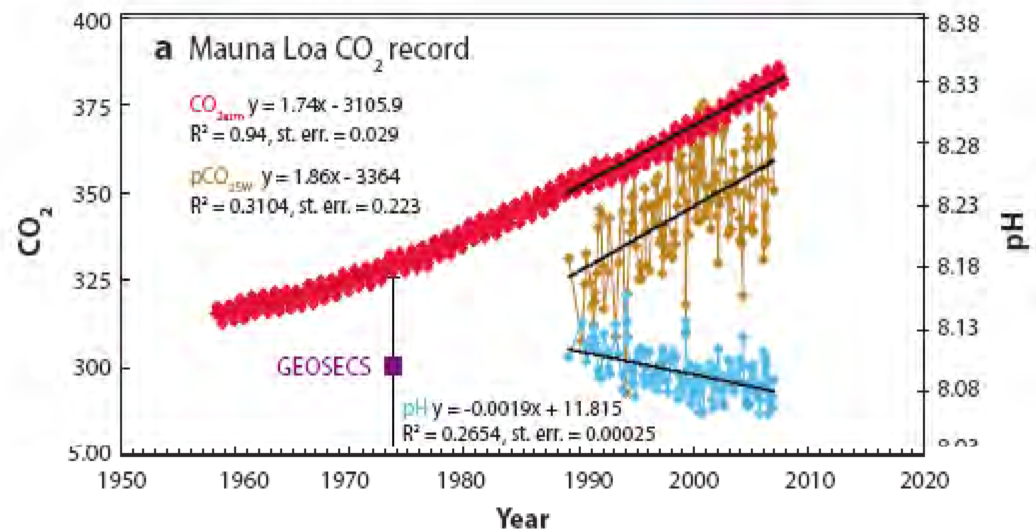
Locations of stations used for this study. The GEOSECS stations were occupied in 1973, the INDOPAC stations in 1976, and the NOAA western North Pacific stations in 1982.

"Our calculations show that one possible effect of fossil fuel-derived CO_2 on the surface of the North Pacific will be a steady progression of undersaturation from the northern to southern and western areas, with the first sign of undersaturation possibly occurring as early as the second half of the next century."

Feely et al., 1984

The "other CO2 problem"

- The ocean takes up about 1/3 of anthropogenic CO_2 emissions
- CO_2 causes acidity of ocean to increase

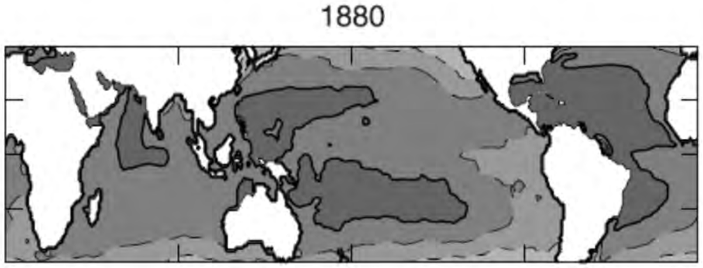


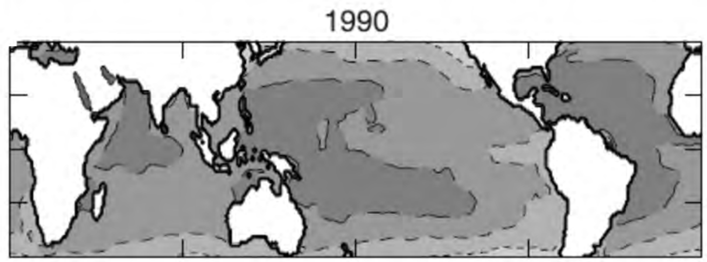
Doney et al. (2009)

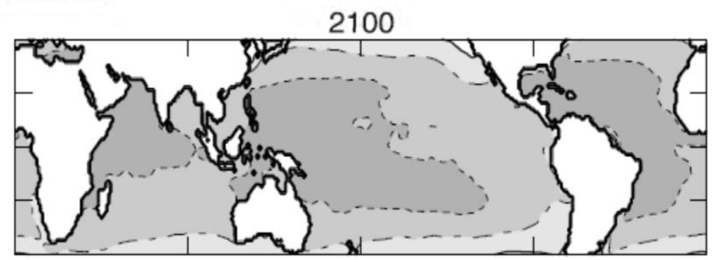
Impacts on Coral Reefs

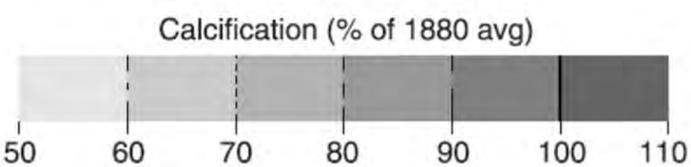
Geochemical Consequences of Increased Atmospheric Carbon Dioxide on Coral Reefs

Joan A. Kleypas,[1*] Robert W. Buddemeier,[2] David Archer,[3] Jean-Pierre Gattuso,[4] Chris Langdon,[5] Bradley N. Opdyke[6]









Kleypas et al., 1999

Projected future changes in calcite saturation state

GLOBAL BIOGEOCHEMICAL CYCLES, VOL. 23, GB1008, doi:10.1029/2008GB003278, 2009

Early detection of ocean acidification effects on marine calcification

Tatjana Ilyina,[1] Richard E. Zeebe,[1] Ernst Maier-Reimer,[2] and Christoph Heinze[3]

Received 29 May 2008; revised 5 August 2008; accepted 20 November 2008; published 19 February 2009.

Canadian Pacific Coast:
We are here

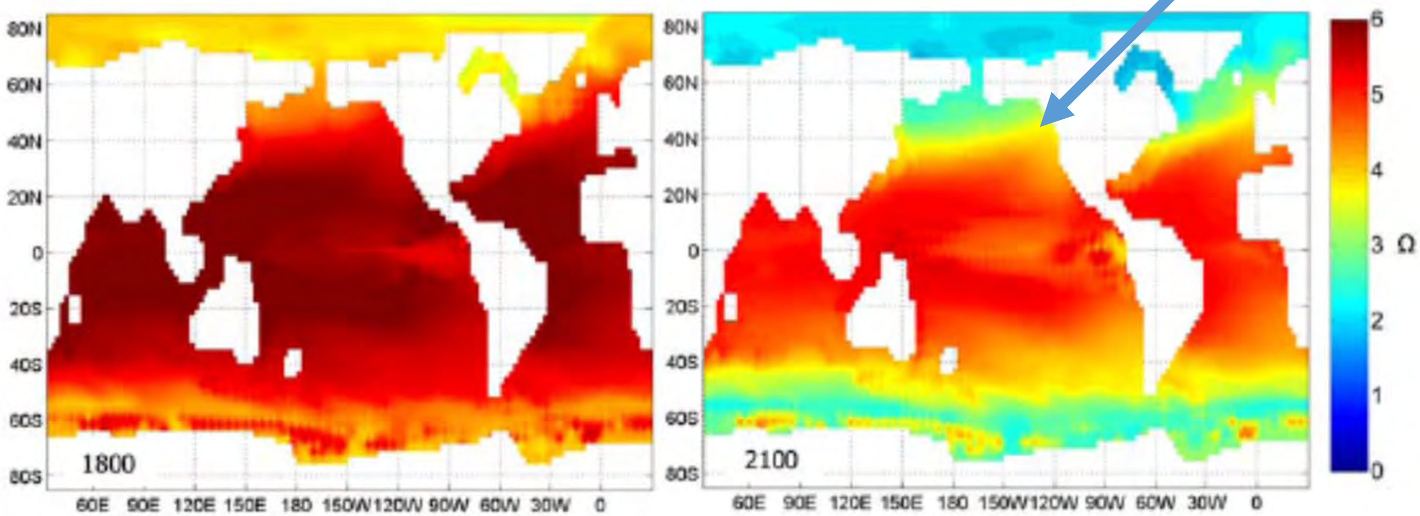


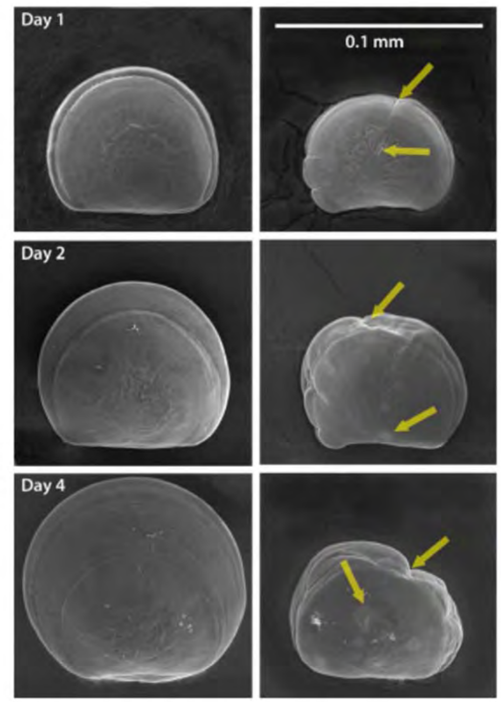
Figure 7. Saturation state of calcite (Ω) calculated under moderate scenario for the years (left) 1800 and (right) 2100.

Implications for marine organisms?

Pteropods

pCO2 = 403ppm
Ωarag = 1.64
pH = 8.00

pCO2 = 1418 ppm
Ωarag = 0.47
pH = 7.49



Scleractinian corals
t = 12 mo, pH = 7.4
Fine & Tchernov (2007).

Pencil urchins
pCO2 = 2850, 400 ppm

Fine and Tchernov, 2007; Doney et al. 2009; Ries et al. 2009
Barton et al. 2015

Marine Environmental Observation Prediction and Response Network MEOPAR

155+ university researchers

150+ highly-qualified people

from 20 universities

Who work with:

35 federal & provincial departments and agencies,

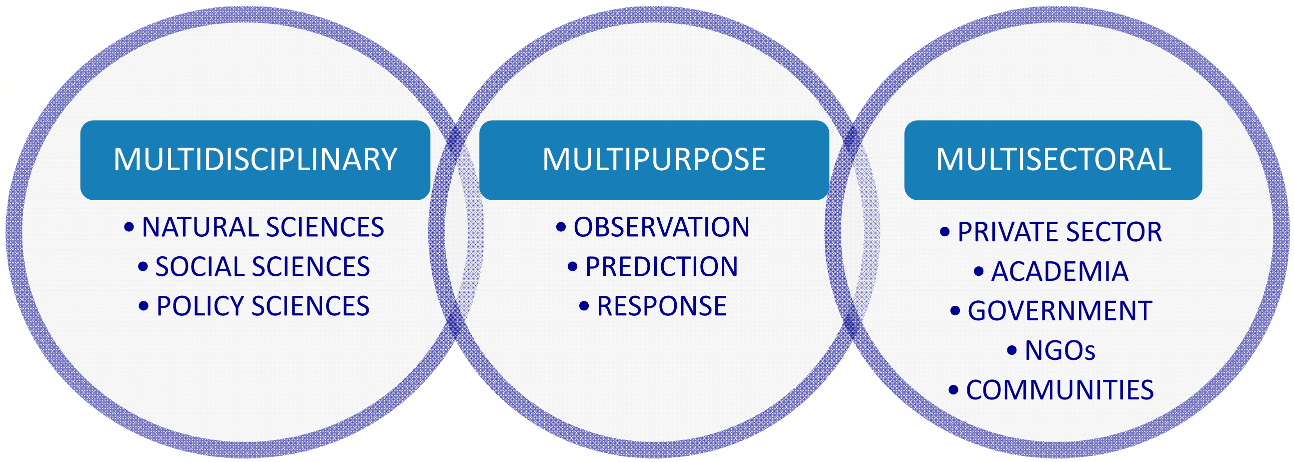
50 industrial and other partners

in Canada and beyond.

DALHOUSIE UNIVERSITY *Inspiring Minds*

$25M Funding (2012-2017) from the Networks of Centres of Excellence

MEOPAR'S Vision: Our Network



Working together to better understand and PREDICT the IMPACT of MARINE HAZARDS on human activities and ecosystems… AND IMPROVE RESPONSE.

Ocean Acidification in Canadian Coastal Communities: An Integrated Coastal Acidification Program (I-CAP) -2015-2018

MEOPAR

How do we go from the open ocean to the beach, where commercial fisheries, coastal ecosystems, *and the people who depend on them* are affected?

I-CAP Investigators and Partners

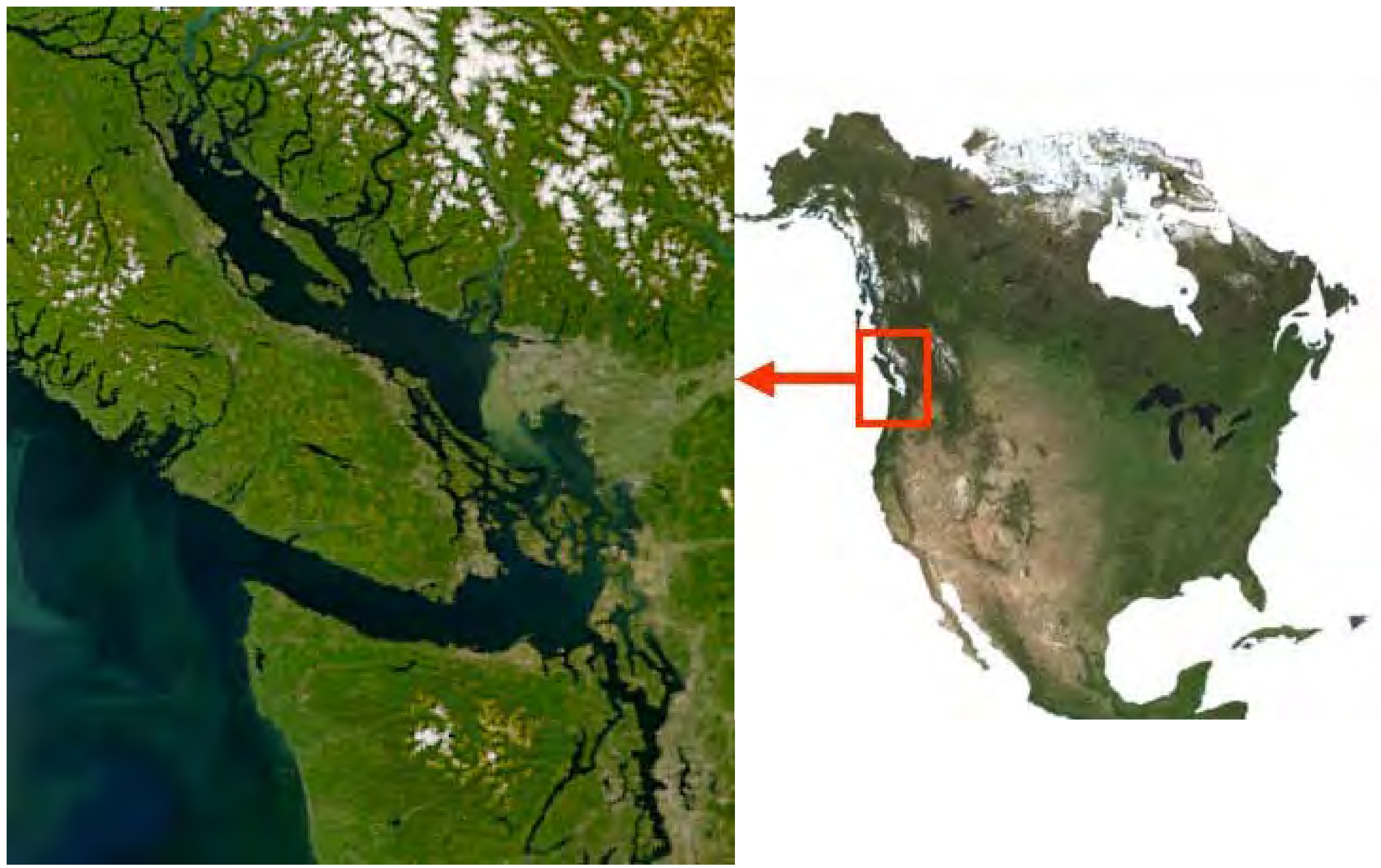
UNIVERSITY
Susan Allen, William Cheung, Chris Harley (UBC)
Piero Calosi (University of Quebec – Rimouski)
Tony Charles (St Mary's University)
Karen Kohfeld (Simon Fraser University)
Julie LaRoche (Dalhousie)
Philip Loring (U Saskatchewan)
Jennifer Silver (U of Guelph)

INDUSTRY
Dounia Daoud (Homarus, Inc.)
Andre Comeau (Okeover Organic Oysters)
Andrew Dryden (Evening Cove Oysters)
Brenden Frehlich (Ocean Protein Canada)
Stephanie King (Sea This Consulting)
Nathan Harb (Salty Dog Seafoods)
Yves Perrault (Little Wing Oysters)
Keith Reid (Stellar Bay Shellfish Ltd)

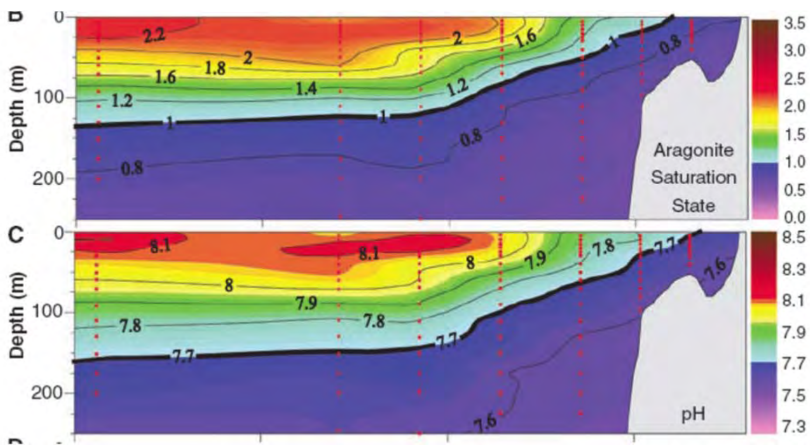
Okeover Inlet, November, 2015: Ellie Simpson (SFU), Aimee McGowan (SFU), Kenny Scozzafava (IOS), Paul Covert (ETH), Andre Comeau (Okeover Organic Oysters), Yves Perrault (Little Wing Oysters)

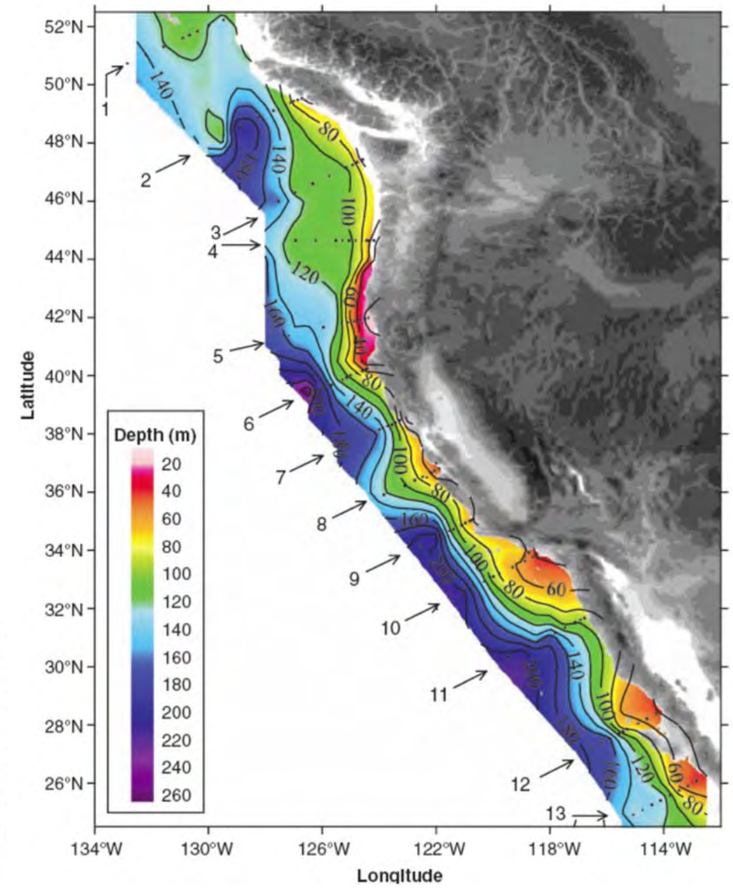
FISHERIES AND OCEANS CANADA
Kumiko Azetsu-Scott (Bedford Inst O, DFO)
Lara Cooper, Helen Gurney-Smith (St Andrews, DFO)
Debby Ianson (Inst. Ocean Sciences, DFO)

Pacific Coast



Pacific Coast: Upwelling of undersaturated water onto the continental shelf





Feely et al. (2008)

Local anthropogenic effects can increase acidity

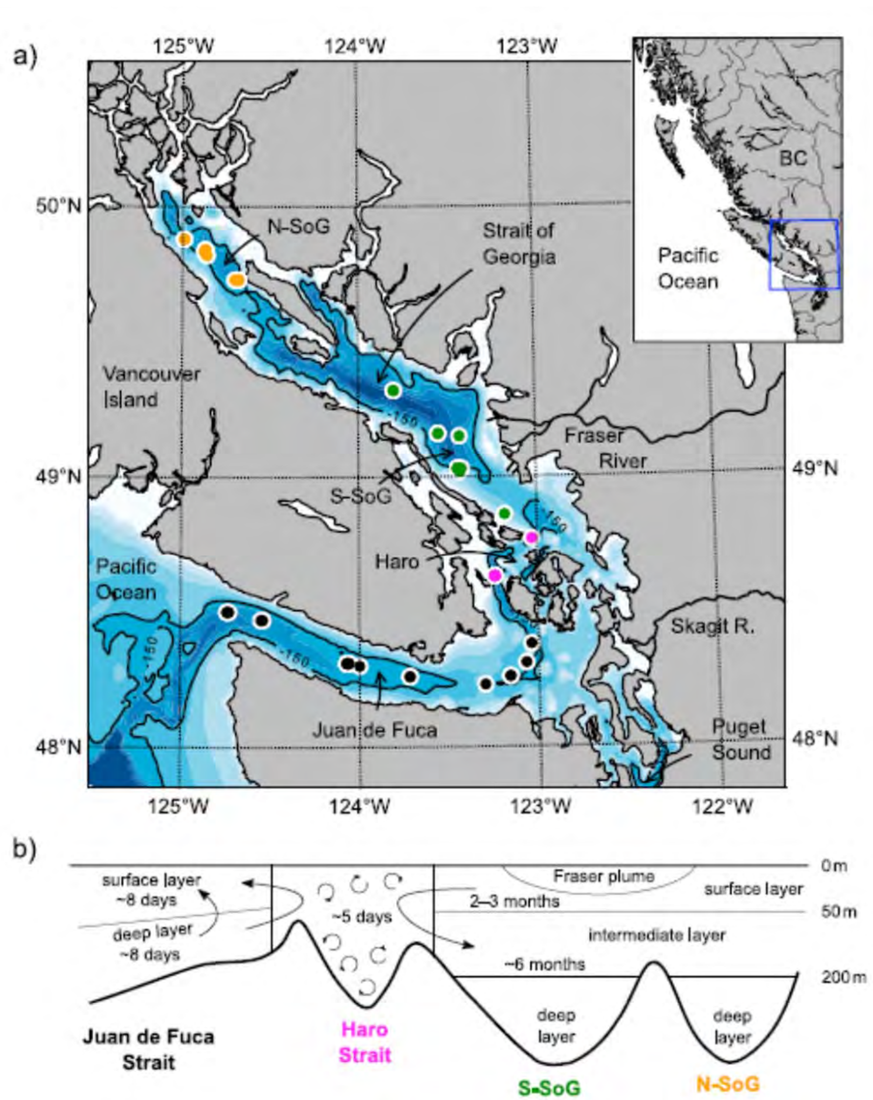
organic carbon decays into CO_2

- sewage adds organic carbon
- agricultural runoff stimulates production of organic carbon

Sewage outfall at Clover Point, Victoria, BC

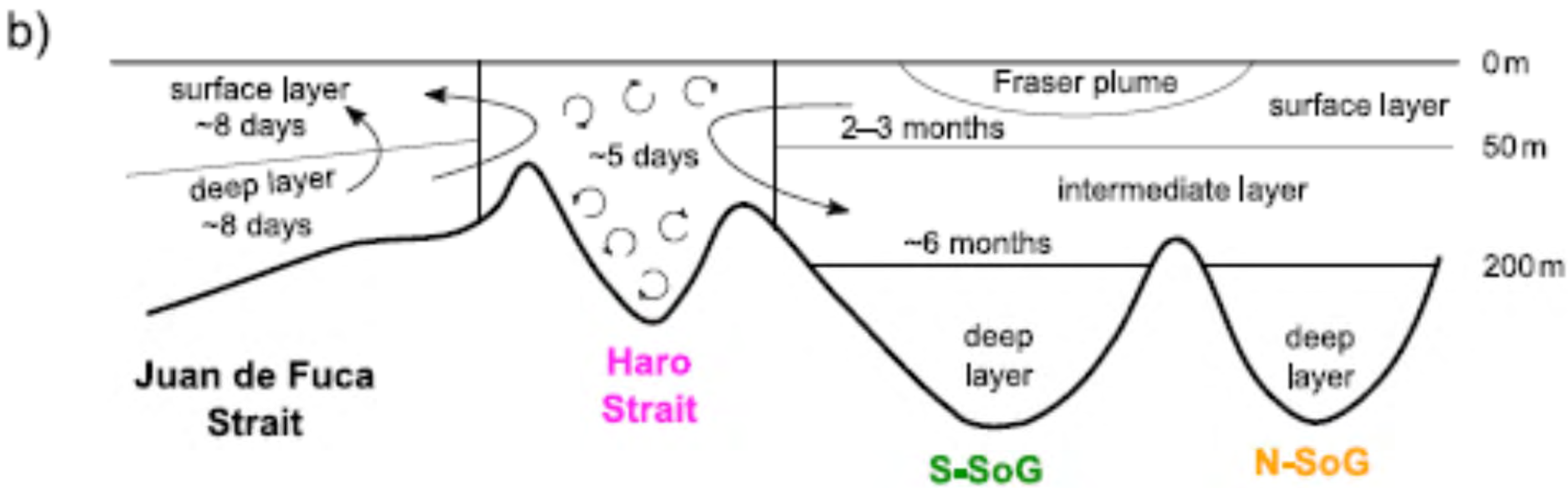
Open-water sampling Strait of Georgia

CCGS Vector



Ianson et al. 2016

Circulation of the Strait of Georgia



Ianson et al. 2016

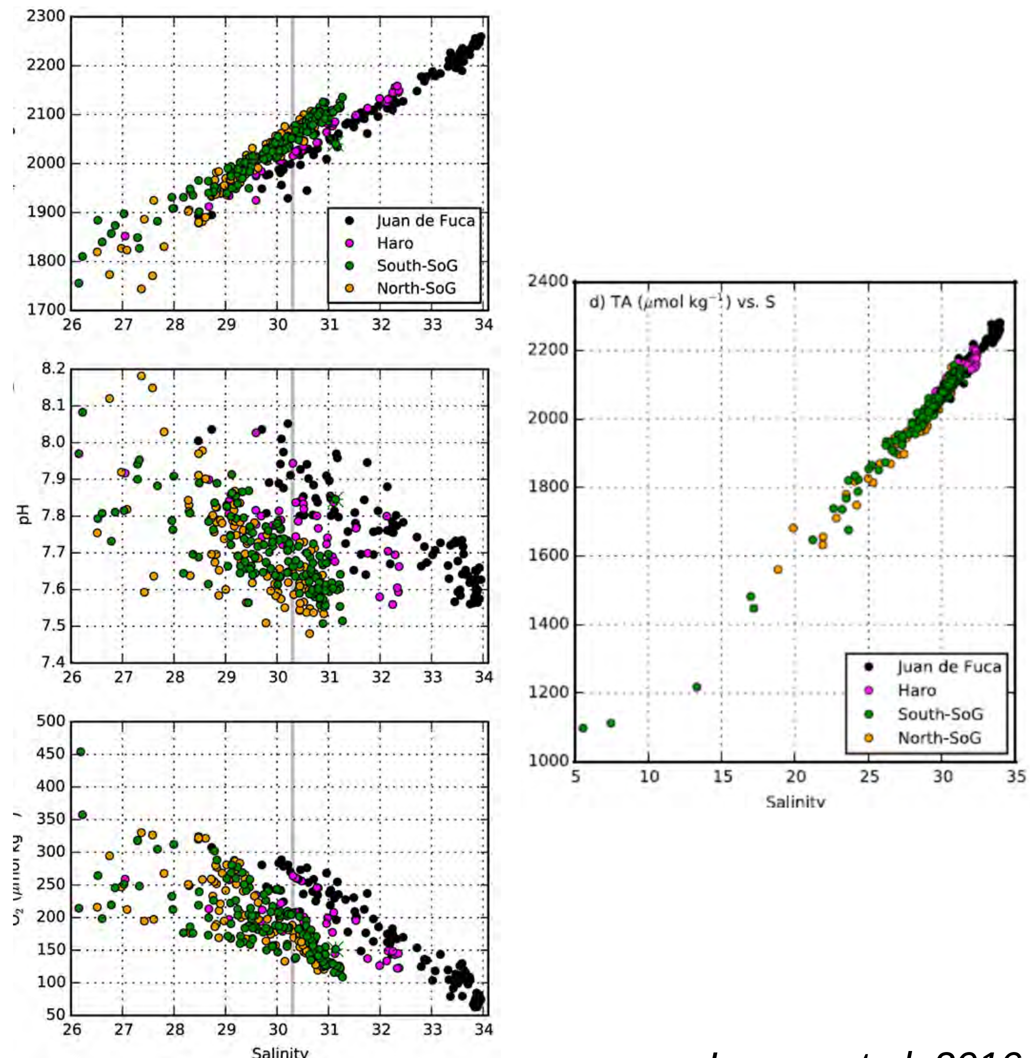
Carbon chemistry

- Strait of Georgia has a high inorganic carbon load and low pH relative to outer coast
- Oxygen uptake (air —> sea) in Haro is significant and protects Strait of Georgia from hypoxia

DIC (μmol/kg)

pH

O_2 (μmol/kg)



Ianson et al. 2016

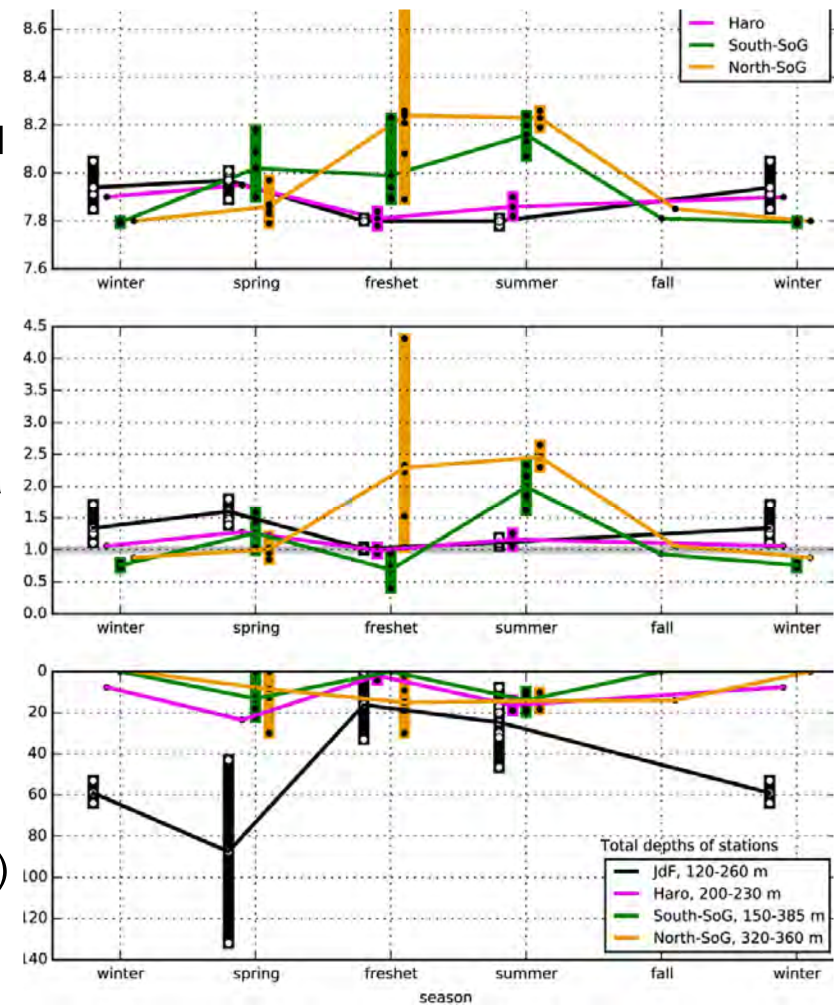
Surface water conditions

- pH (and Ω) high in summer and low in winter
  - winter values 7.8
- Saturation horizon to 20-30 m during Spring bloom
- Entire water column undersaturated in winter

Surface pH

Surface Ωa

aragonite saturation horizon (m)

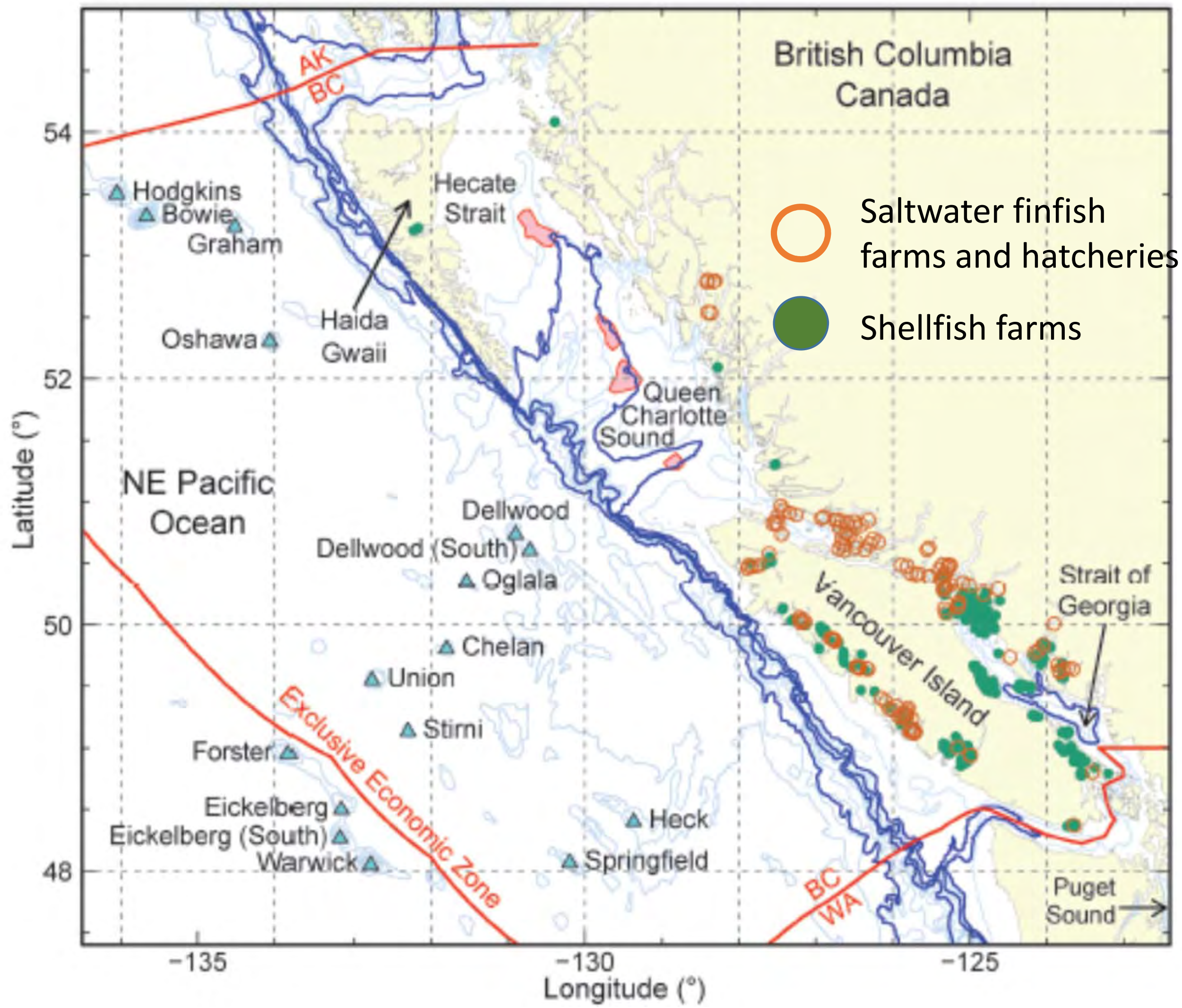


Ianson et al., 2016; Moore-Maley et al. 2016

BC Coast shellfish activities

Fisheries and aquaculture contributes >$CAD 650 M to BC GDP (2011)

Baynes Sound: ~50% of aquaculture activities



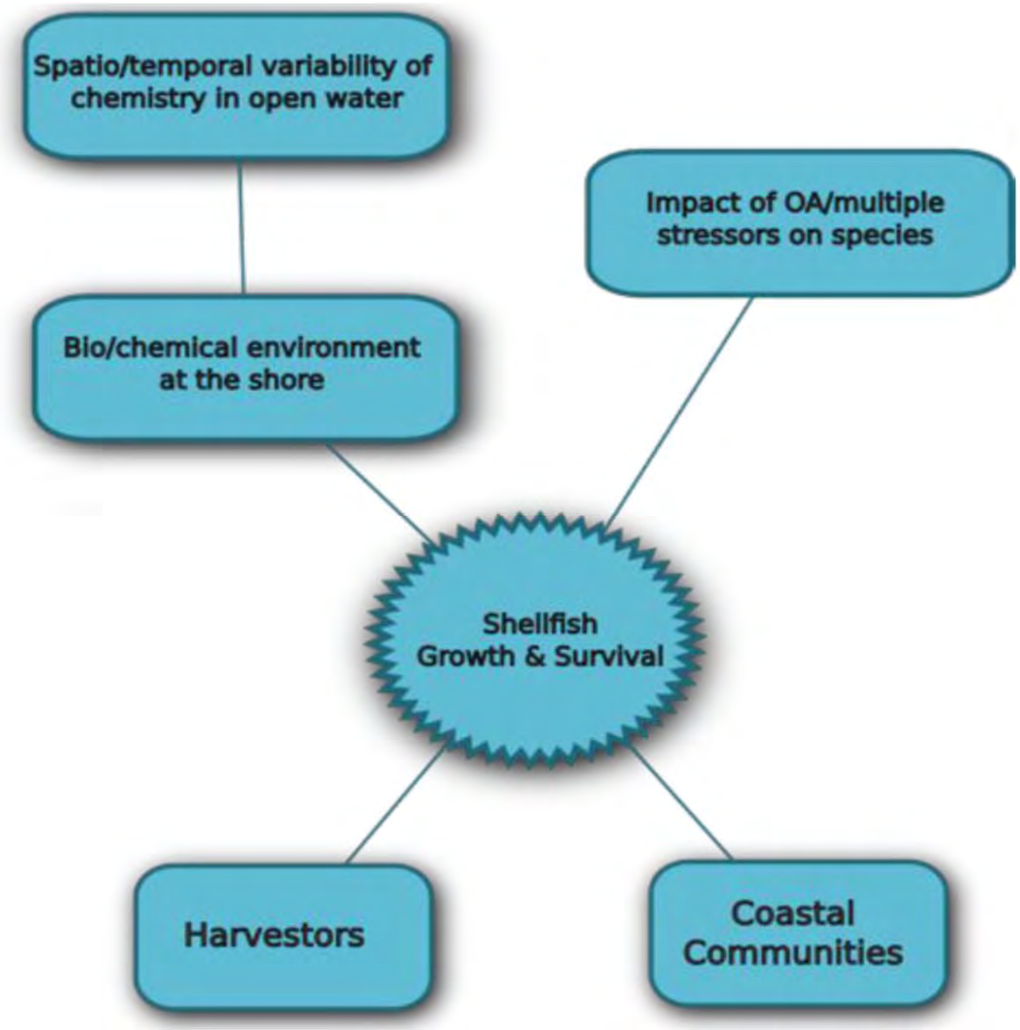
Haigh et al. 2015

ICAP – What is Impact of Coast Acidification on the Canadian Coast

FOUR KEY THEMES

- What is the spatial and temporal variability of carbonate chemistry in near-coastal areas where harvesters are operating?
- What are the dominant controls on this variability?
- How does this variability affect species important to harvesters and coastal communities?
- What are the socio-economic risks to coastal communities?

I-CAP Approach:



Near-Shore Sampling where the shellfish live

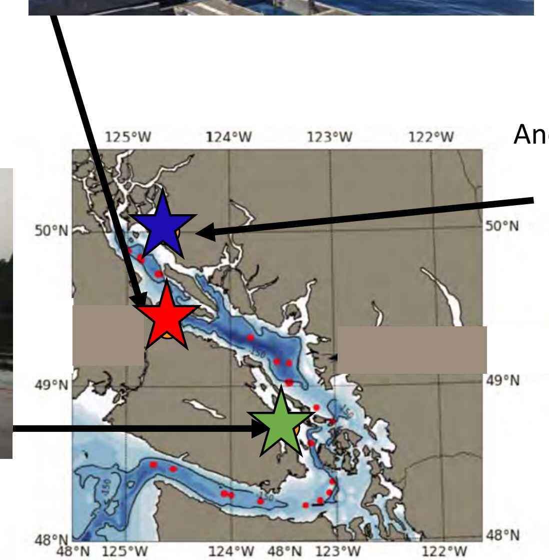
Contending with:

- Run-off
- freshwater lens
- Tidal wetting and drying

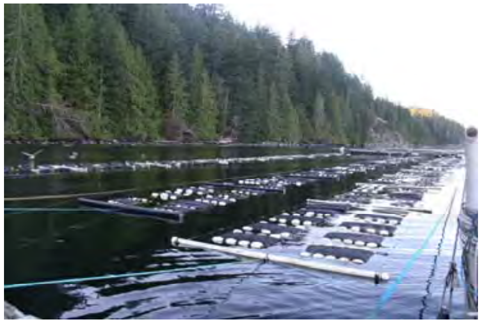
BAYNES SOUND
Keith Reid (Stellar Bay Shellfish Ltd)

SAMSUM NARROWS
Stephanie King (Sea This Consulting)
Terry Learmonth (Salty Dog Seafoods)

Carolyn Prentice (SFU)



OKEOVER INLET
Yves Perrault (Little Wing Oysters)
Andre Comeau (Okeover Organic Oysters)

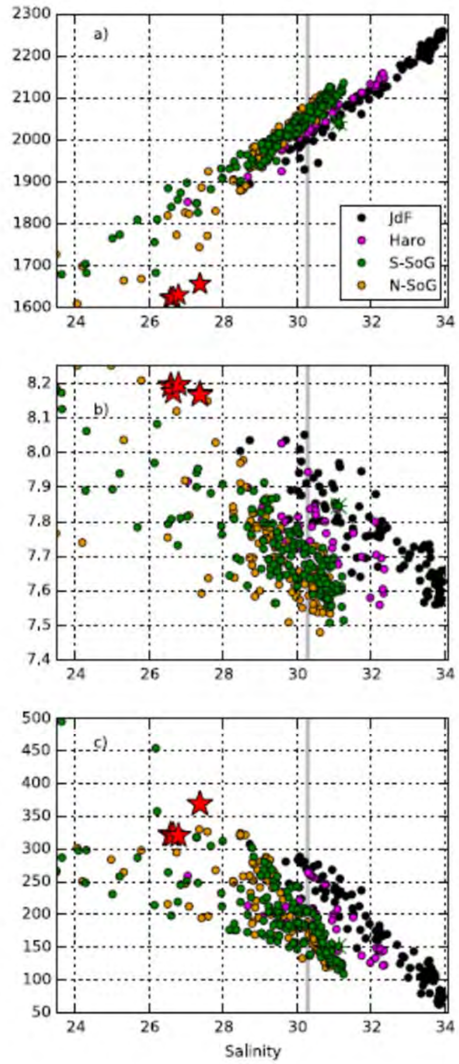


Sampling where the shellfish live

DIC umol/kg

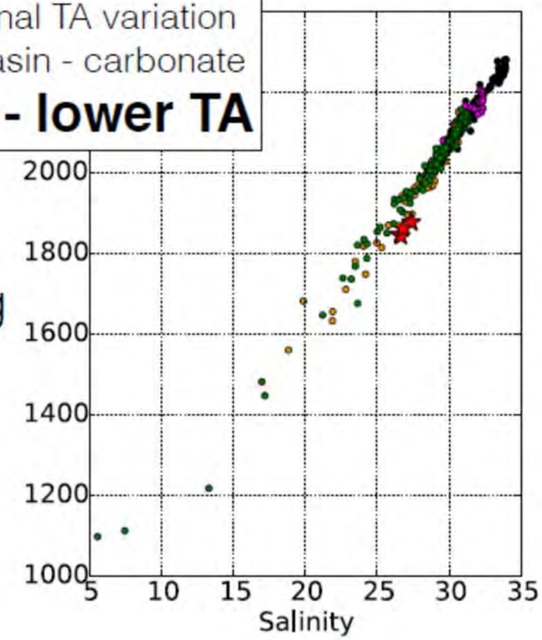
pH

O2 umol/kg



no regional TA variation
Fraser basin - carbonate
shore - lower TA

TA umol/kg



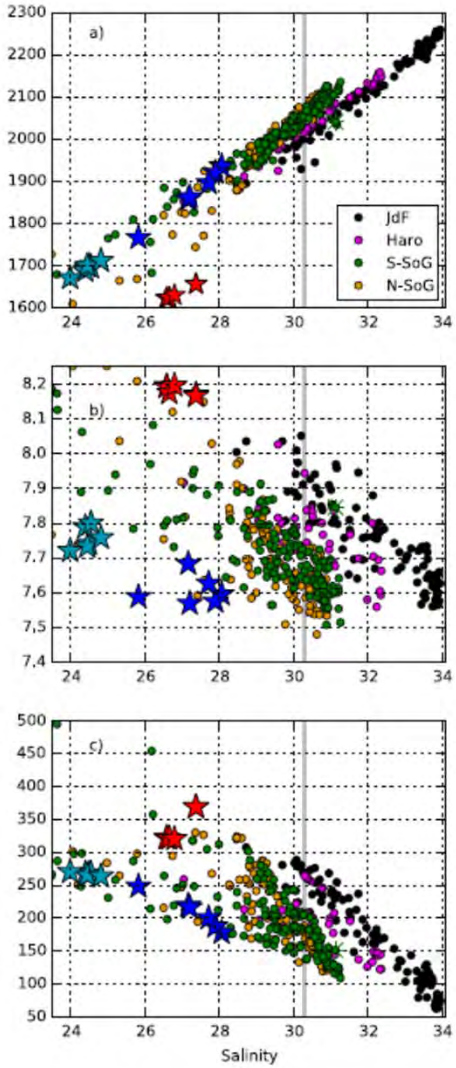
Summer - clam beach ★

high productivity LOW DIC
HIGH O2
but only moderate/high pH

DIC
umol/kg

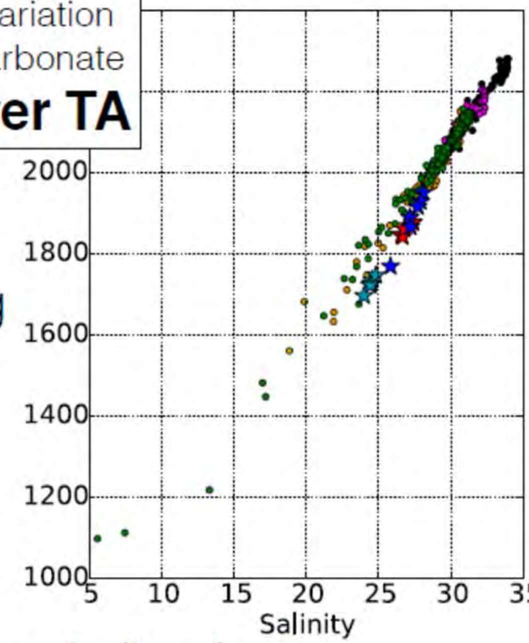
pH

O_2
umol/kg



no regional TA variation
Fraser basin - carbonate
shore - lower TA

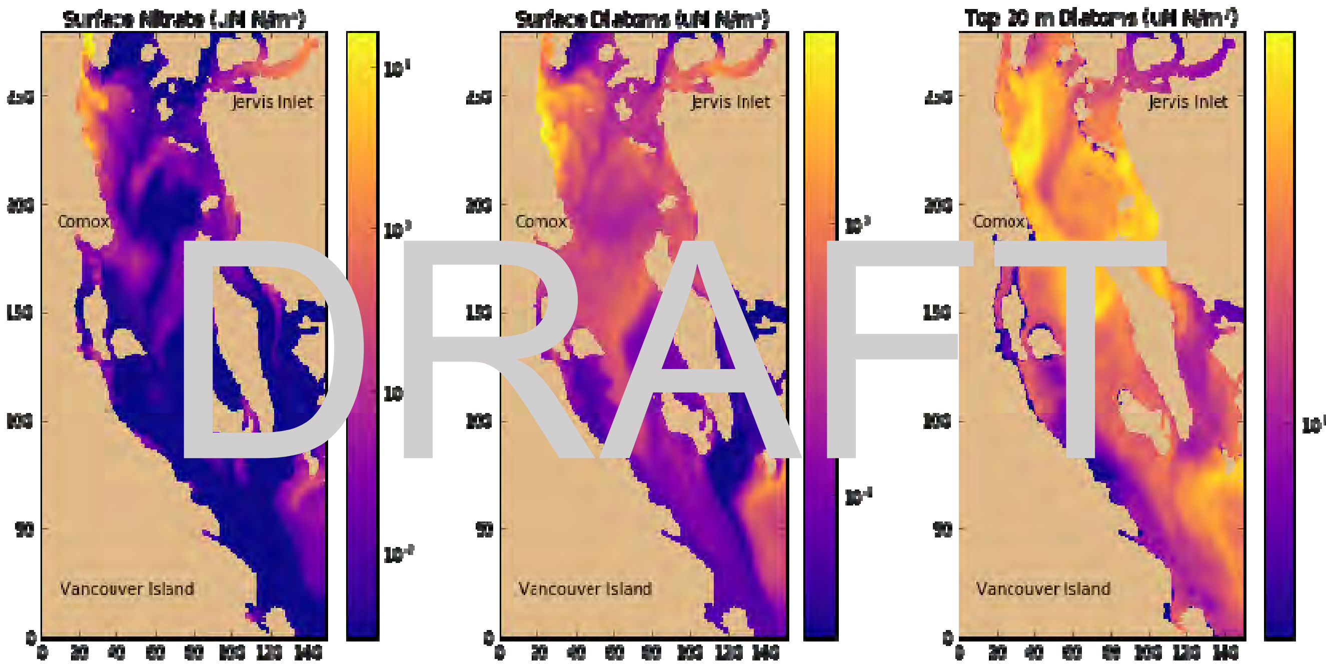
TA
umol/kg



Winter - fresh fjord
(trays and beach)

DIC similar to SoG
low (winter) O2
low pH

Up and coming: Carbon models of the Salish Sea



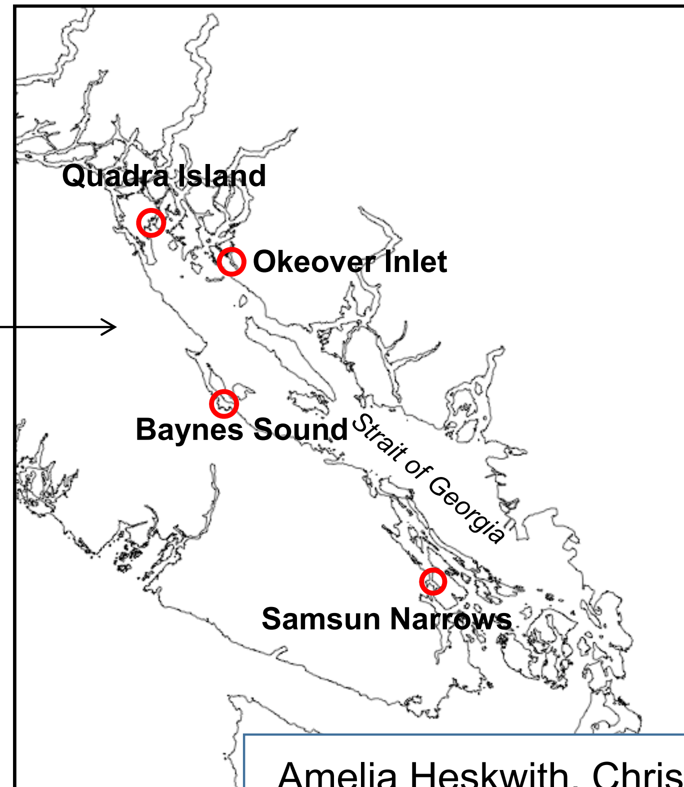
S. Allen, T. Jarnikova (UBC)

How is the Pacific oyster (*Crassostrea gigas*) affected by different pH and carbonate conditions in the Strait of Georgia (SoG)?

Oysters from spat (0.5 in. shell) to cocktail size (2 in. shell) will be outplanted in racks and on beaches.

Subtidal racks

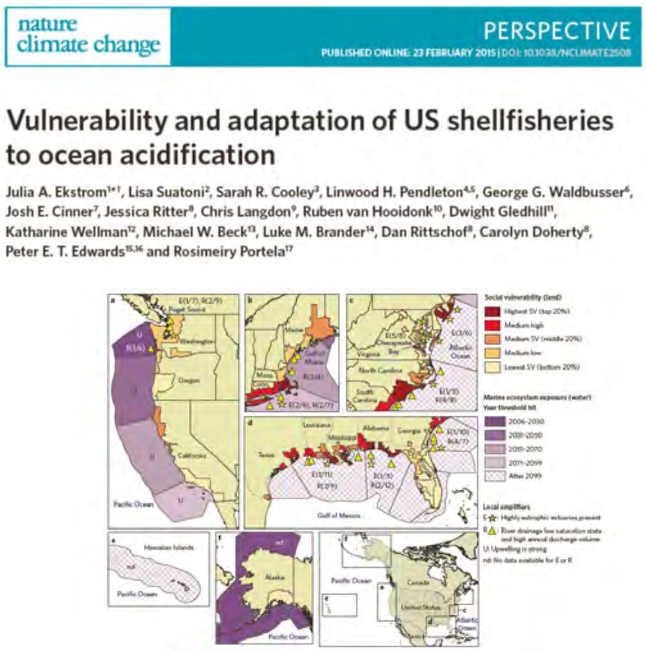
Intertidal outplant



Mortality, growth, and condition will be measured every month for 7 months and related to seawater temperature, salinity, pH, DIC, and chlorophyll concentration.

Amelia Heskwith, Chris Harley (UBC)

Socio-economic risks to Canadian Coastal Communities


nature climate change

PERSPECTIVE

PUBLISHED ONLINE: 23 FEBRUARY 2015 | DOI: 10.1038/NCLIMATE2508

Vulnerability and adaptation of US shellfisheries to ocean acidification

Julia A. Ekstrom[1*†], Lisa Suatoni[2], Sarah R. Cooley[3], Linwood H. Pendleton[4,5], George G. Waldbusser[6], Josh E. Cinner[7], Jessica Ritter[8], Chris Langdon[9], Ruben van Hooidonk[10], Dwight Gledhill[11], Katharine Wellman[12], Michael W. Beck[13], Luke M. Brander[14], Dan Rittschof[8], Carolyn Doherty[8], Peter E. T. Edwards[15,16] and Rosimeiry Portela[17]

- Assessing exposure, vulnerability and adaptive capacity of BC Coast
  - Ellie Simpson (REM - SFU), Debby Ianson (IOS), Karen Kohfeld (SFU), Sarah Cooley (Nature Conservancy), Murray Rutherford (SFU)

Conclusions

- Inlets and fjords of the Canadian Pacific coast are unique relative to the open coast
- Strait of Georgia has a high inorganic carbon load and low pH relative to outer coast
- Oxygen uptake in Haro Strait is significant and protects Strait of Georgia from hypoxia
- Surface pH and Ωa is high in summer and low in winter, and in fact the entire water column is under-saturated in winter
- Thus far at the shore conditions are more variable but reflecting same patterns as the Strait
- Future work combines observations, modeling, in-situ biological experiments and social-economic assessments

Thank you!

E. Simpson (SFU)