



The story so far: an *in situ* pairing of chemical oceanography and ocean acidification physiological responses

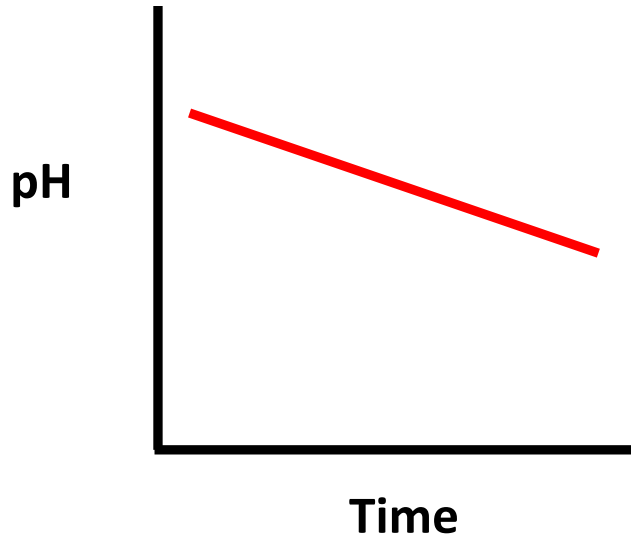
H. Gurney-Smith*, K. Mohns, C. Smith, T. Brown,
A. Haegert, G. Reid, M. Raap, B. Collicutt & W. Evans

June 8, 2018

ECCWO-4 International Symposium



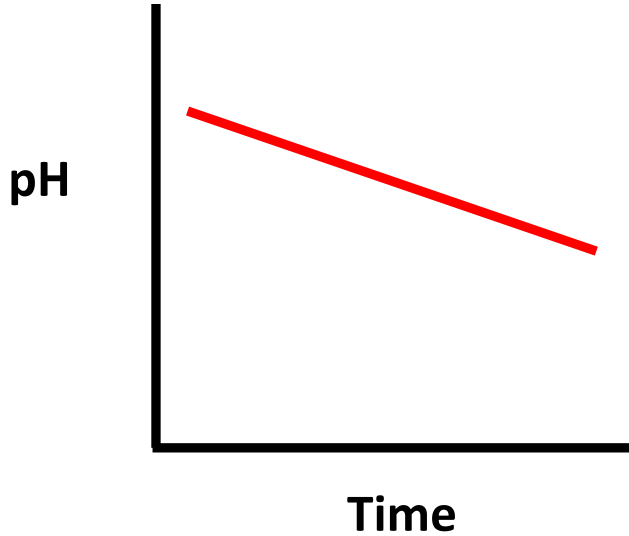
pH on global and local scales



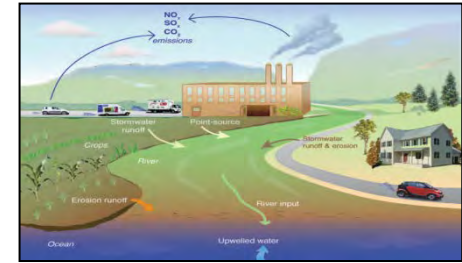
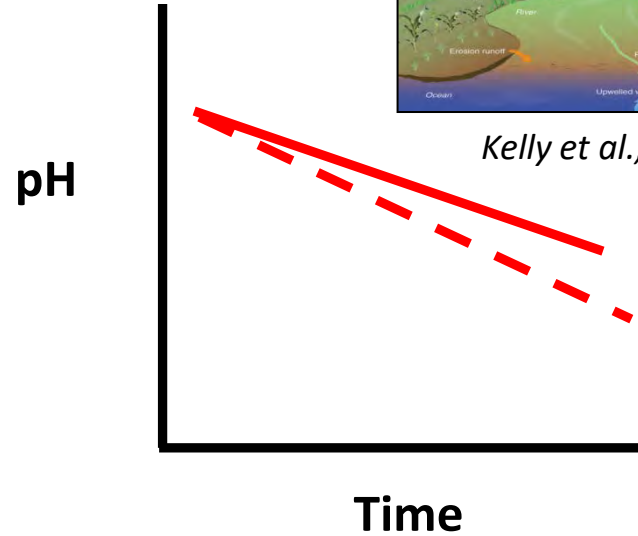
Global ocean pH declined by 0.1 unit since industrial revolution from OA (Orr et al., 2005). **Expected decrease by another 0.5 unit by end of 2100** (IPCC projections)



pH on global and local scales



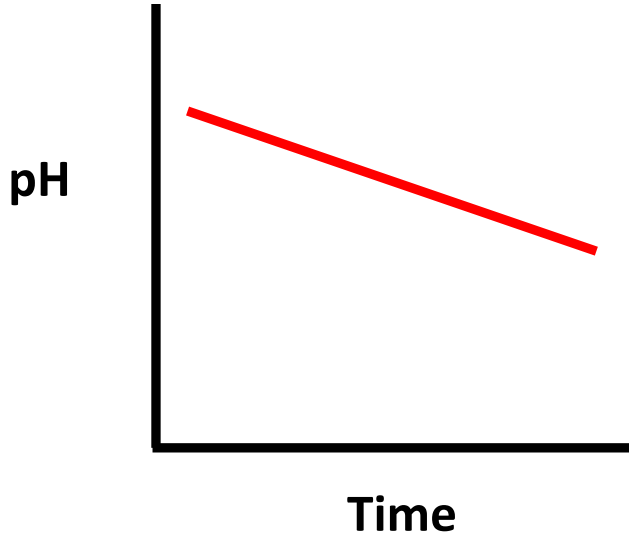
Global ocean pH – biological studies



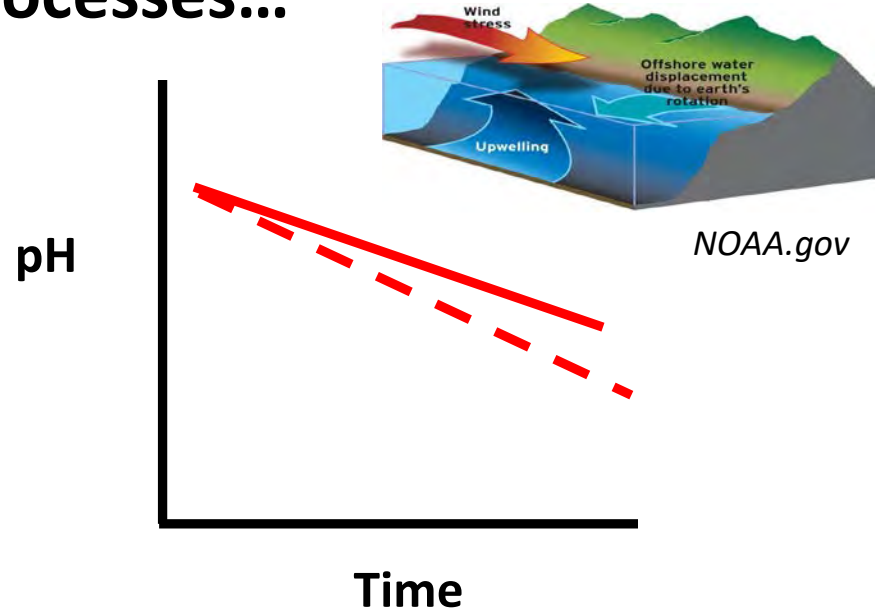
Kelly et al., 2011 Science



add physical processes...

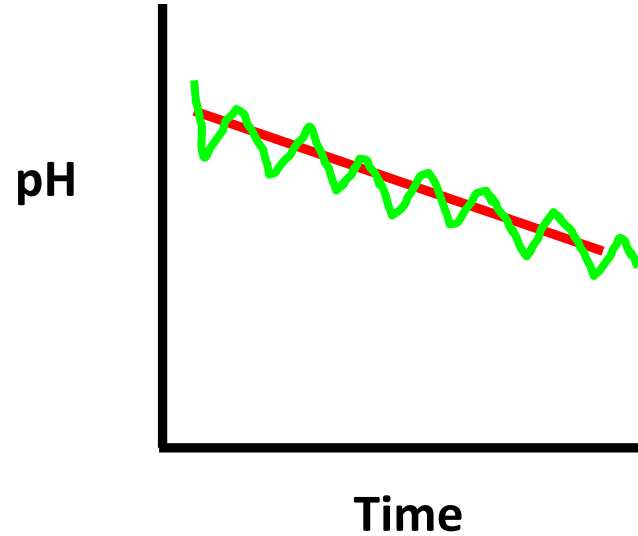
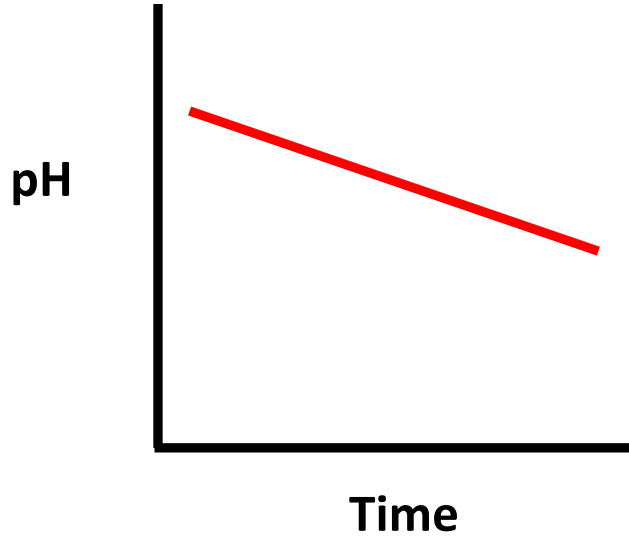


Global ocean pH – biological studies



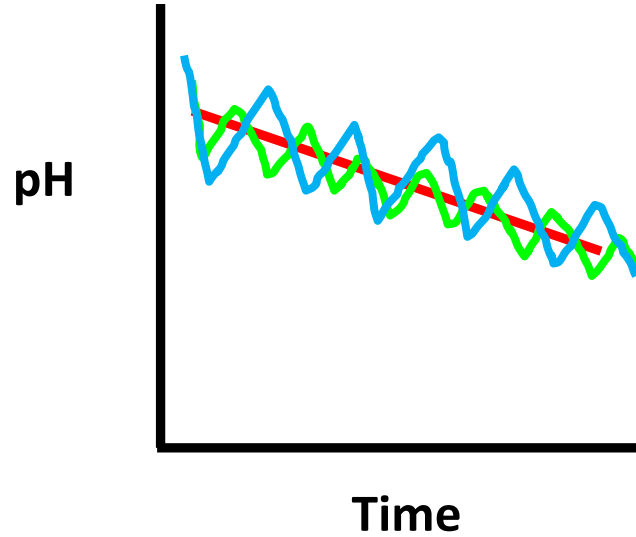
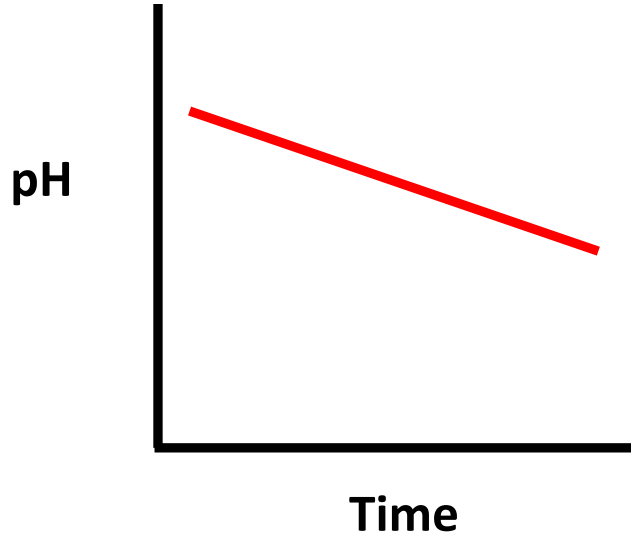


plus daily fluctuations...



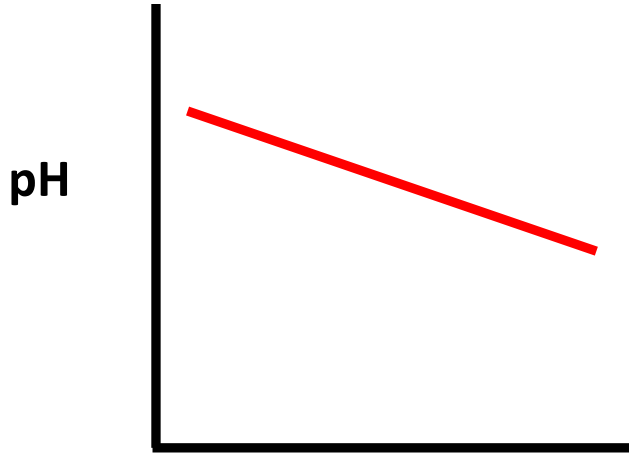
Global ocean pH – biological
studies

seasonal changes...



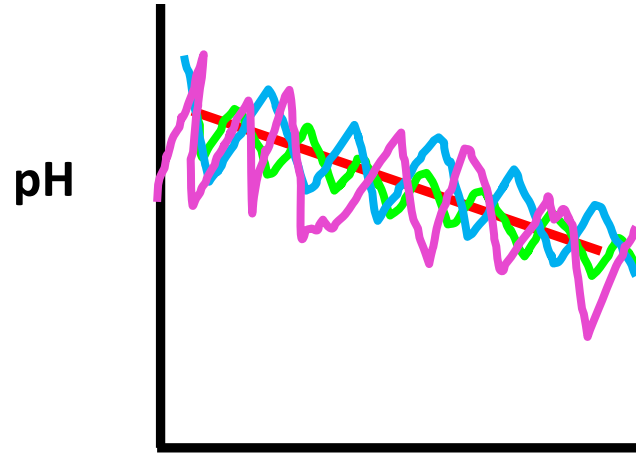
Global ocean pH – biological studies

and weather, extreme events, climate patterns and anomalies...

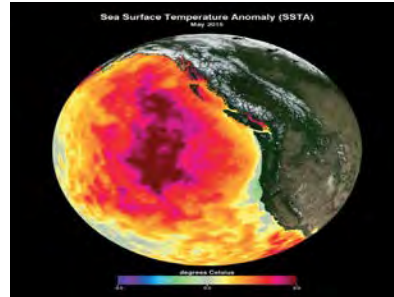


Time

Global ocean pH – biological studies

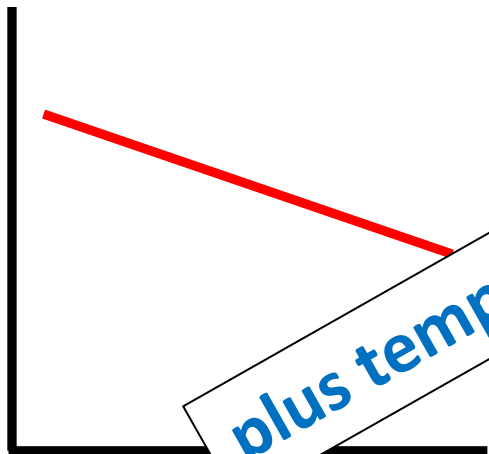


Time



Gentemann et al., 2017, *Geophys. Res. Lett.*

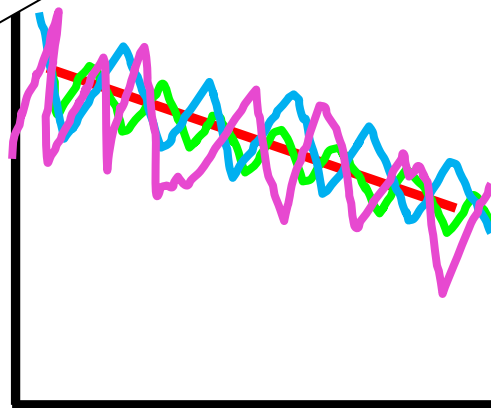
pH



Time

plus temperature, salinity, currents, etc....!

pH



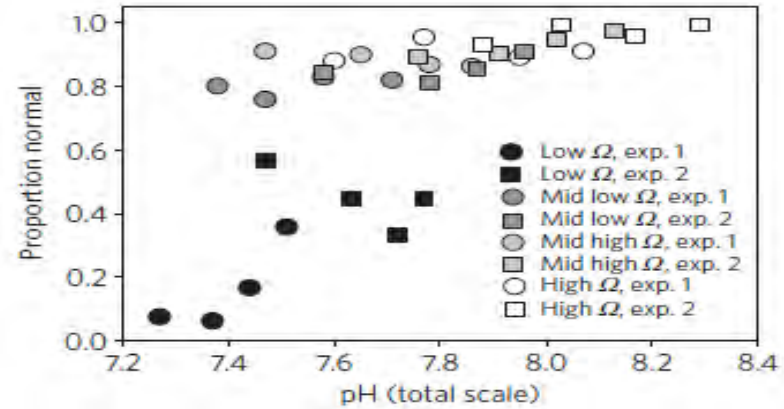
Time

Global ocean pH – biological studies



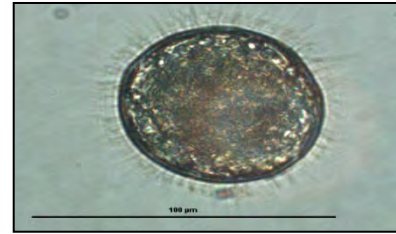
Rationale and Approach

1. Known impacts on calcifiers like bivalves
2. **The bigger picture** - multiple trophic layers of coastal systems
3. **In situ** 'vs' controlled laboratory study
4. Concentrating on **calcium carbonate saturation** (monitoring)
5. **Multidisciplinary approach**



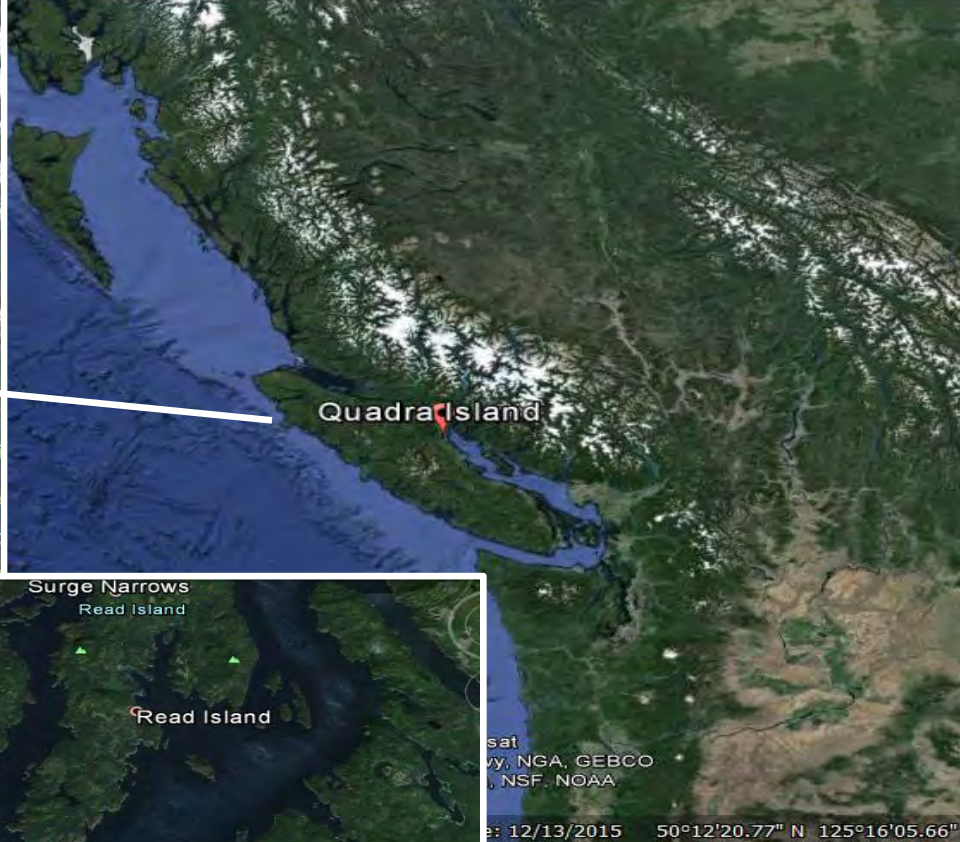
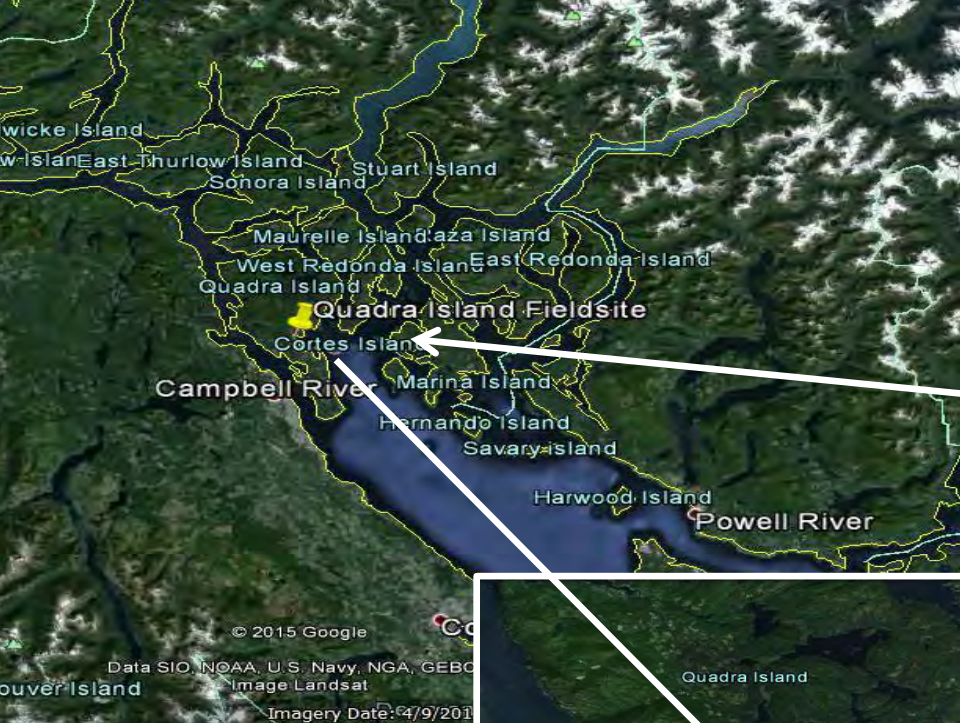
Pacific Oyster (Crassostrea gigas)

Waldbusser et al., 2014 *Nature Climate Change*

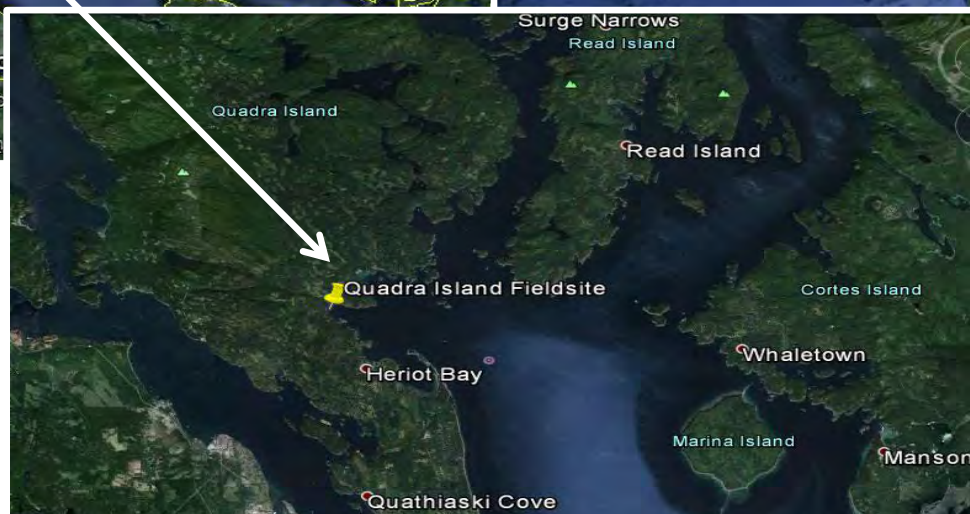


Oysters in deep trouble: Is Pacific Ocean's chemistry killing sea life?

Ocean Acidification Devastates Oyster Farms in the Pacific Northwest



Quadra Island field site (highly dynamic environment with multiple inputs)

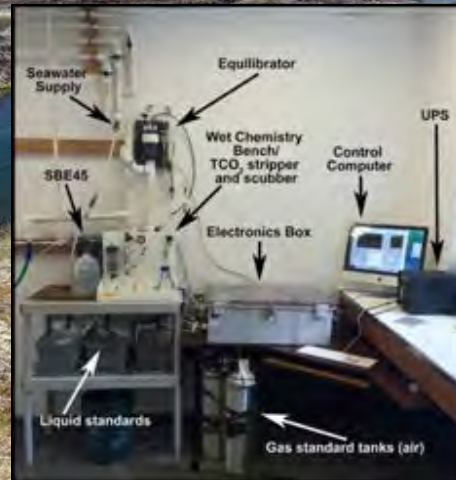


Experimental Setup – *in situ*



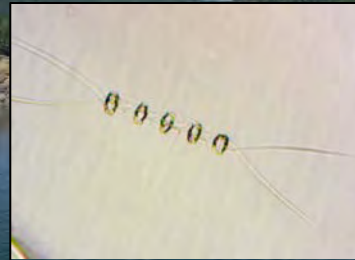
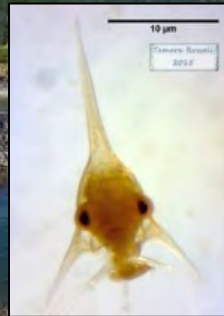
Chemical oceanography

- Sunburst Super CO₂ 2014-2016
- Combined pCO₂, TCO₂ analyzer 2016 -
- SST, salinity, pCO₂, TCO₂



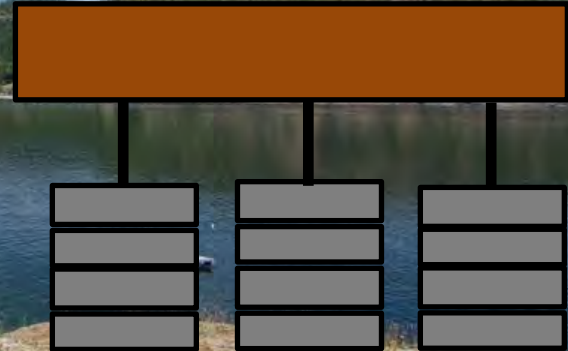
Plankton sampling – food quantity and quality

- Phytoplankton
- Zooplankton



Shellfish sampling - physiology

- Seasonal and targeted
- Multiple tissues
- Multiple commercial species

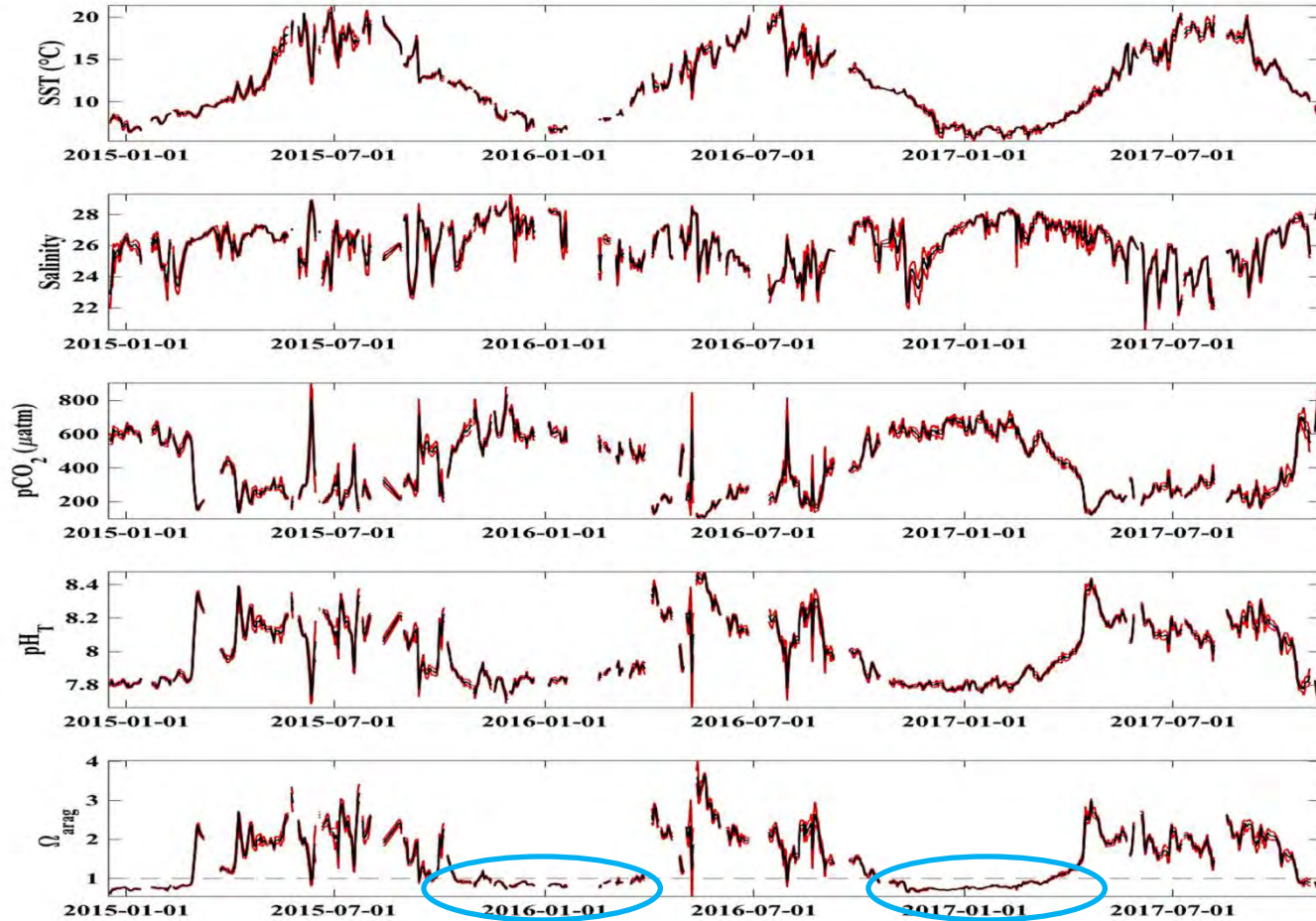


Shellfish sampling - physiology

- **Seasonal and targeted**
- **Multiple tissues**
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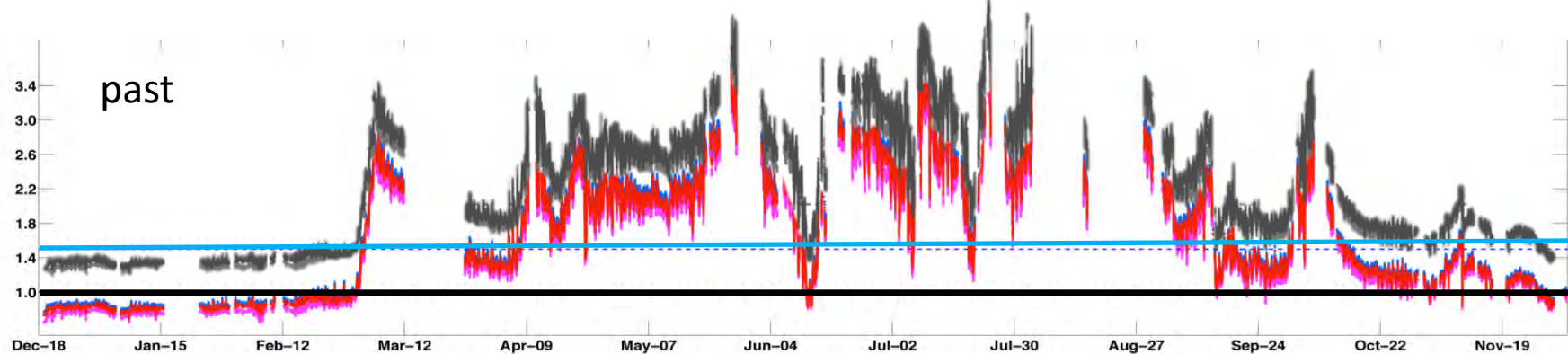


Chemical Oceanography

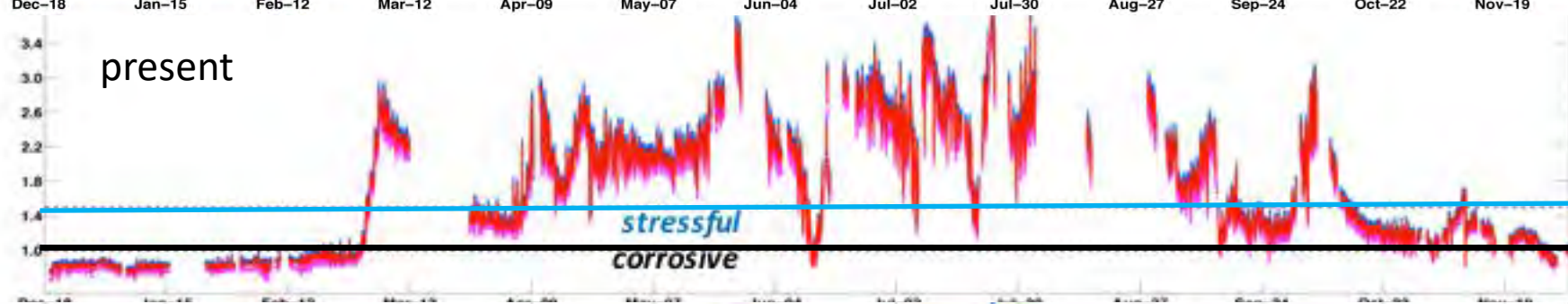


Ω_{arag}

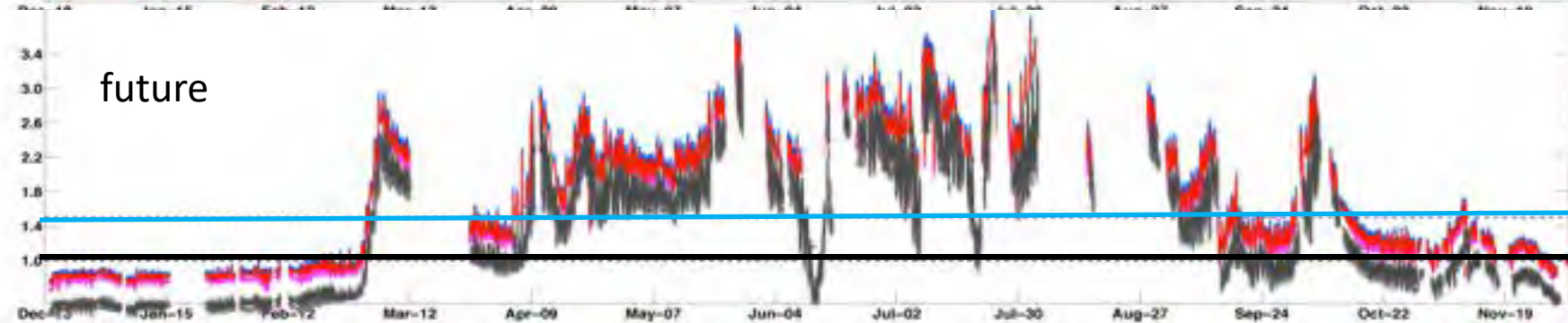
past

 Ω_{arag}

present

 Ω_{arag}

future

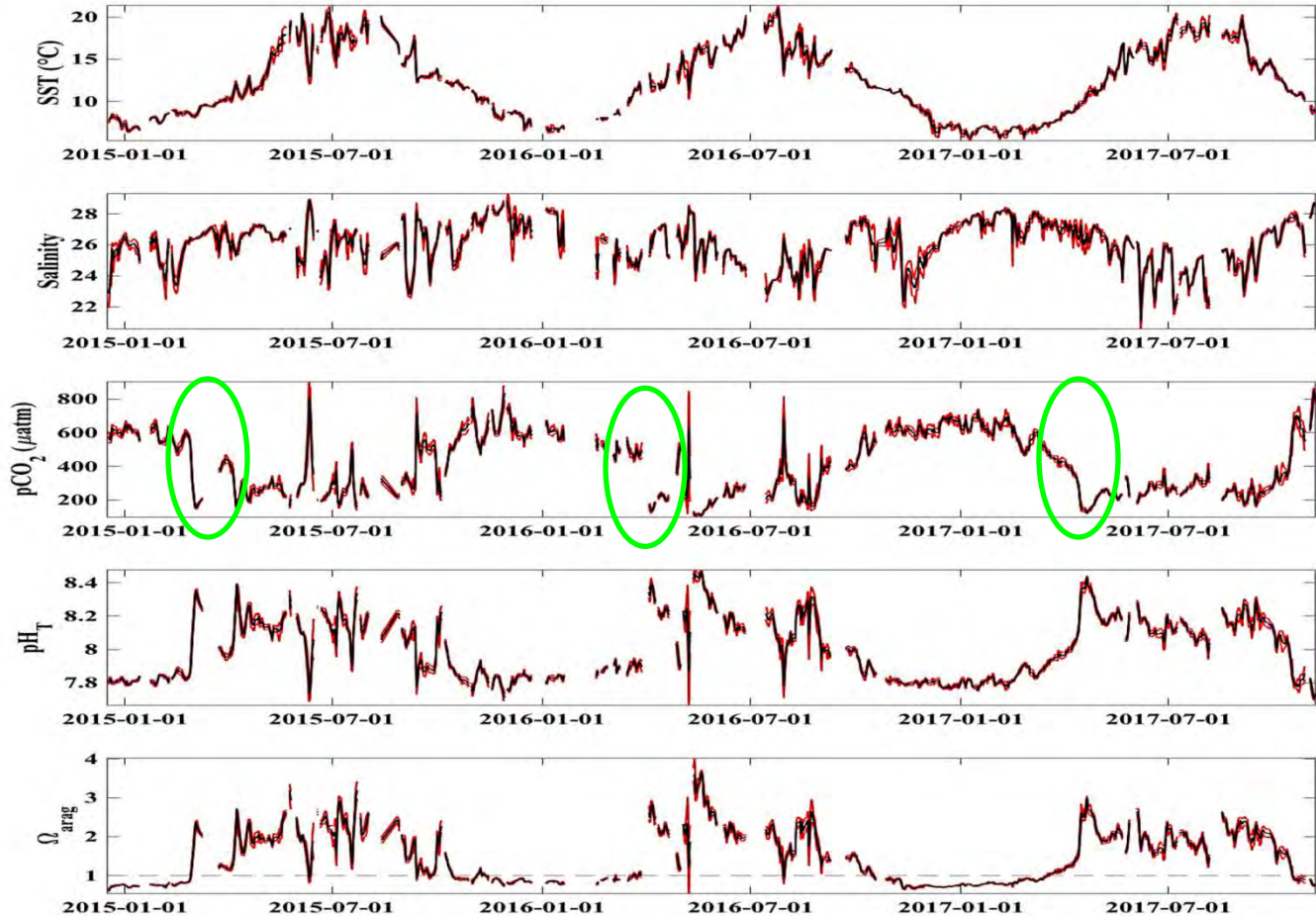


Phytoplankton blooms

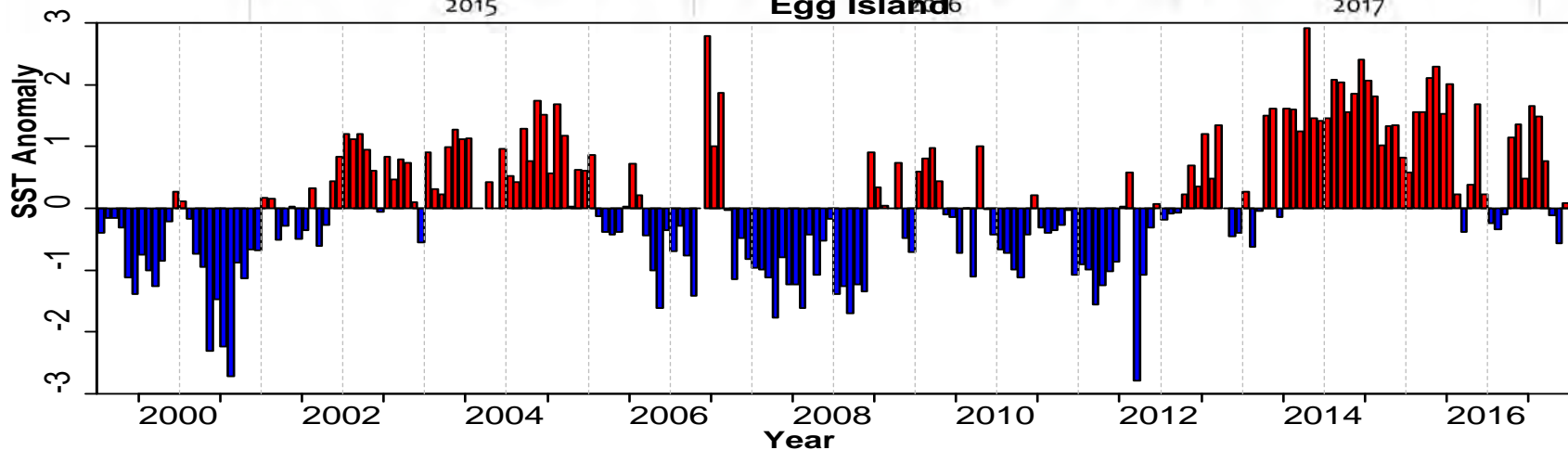
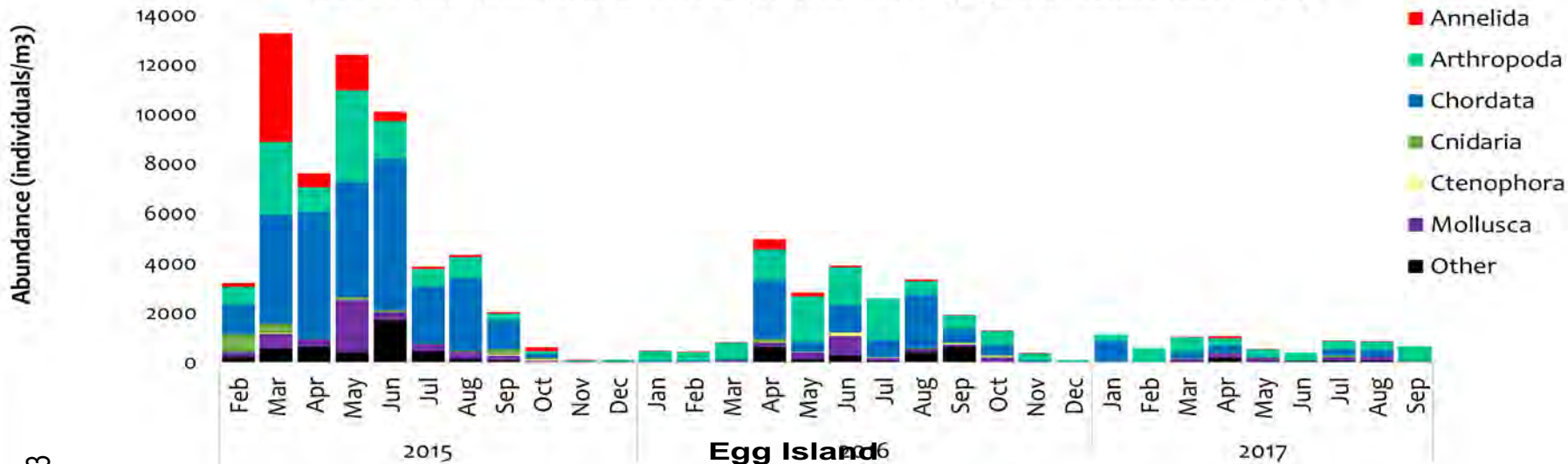
• **2015** early bloom, dense biomass

• **2016** low productivity, coccolithophore bloom (August)

• **2017** late, lowest biomass

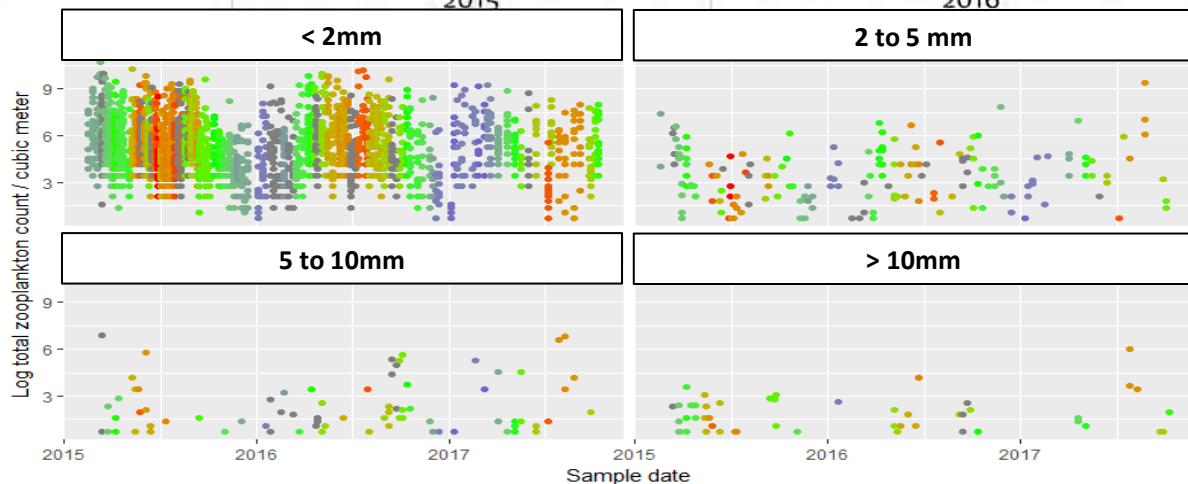
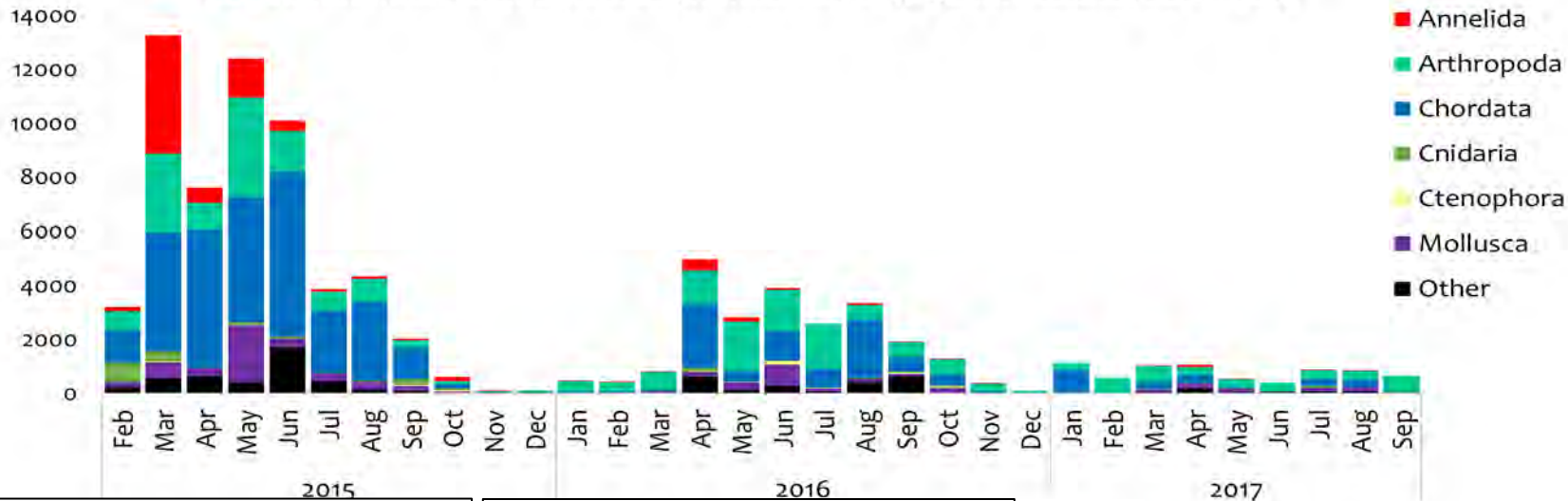


Zooplankton mean abundance (individuals/m³), Quadra Island, 2015 - 2017



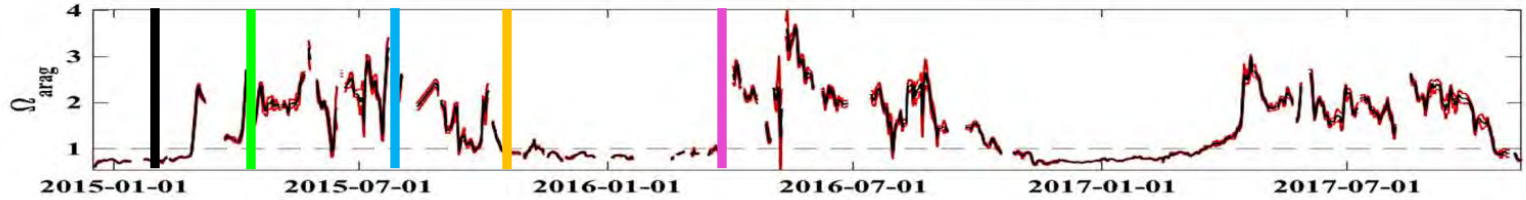
Zooplankton mean abundance (individuals/m³), Quadra Island, 2015 - 2017

Abundance (individuals/m³)

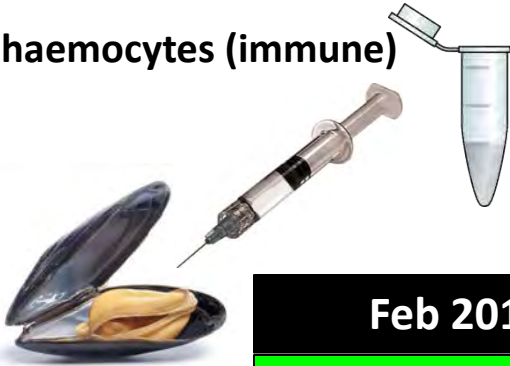


- No changes in plankton size
- Dominance small zooplankton
- Poor quality copepod (Sockeye, Coho, Chinook)
- Dominance larvaceans and jellyfish (Pink, Chum)
- Migration Johnstone Strait

Shellfish physiology - targeted



haemocytes (immune)



Feb 2015 - winter

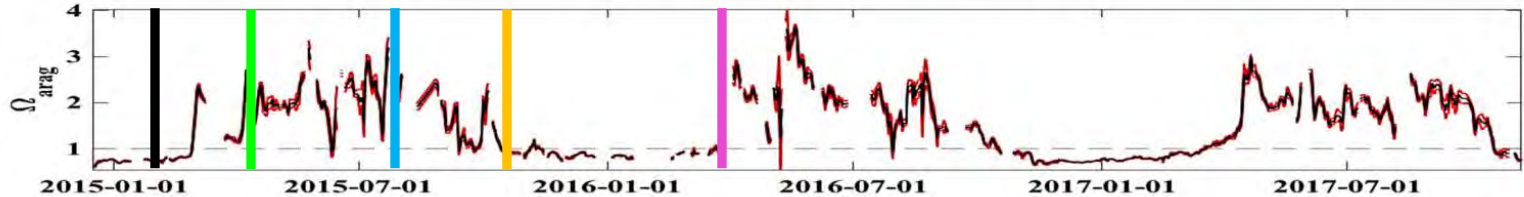
Apr 2015 – pre-spawn

July 2015 – post-spawn

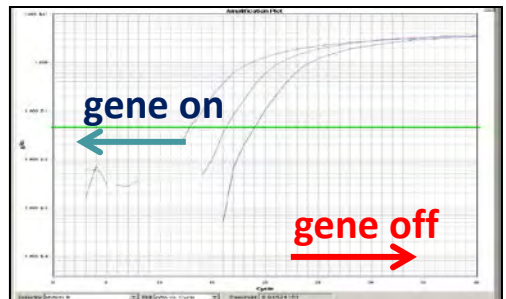
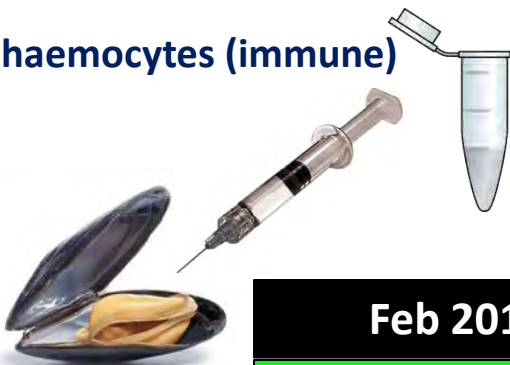
Oct 2015 – gametogenesis

Apr 2016 – transition

Shellfish physiology - targeted



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50 genes qPCR

Feb 2015 - winter

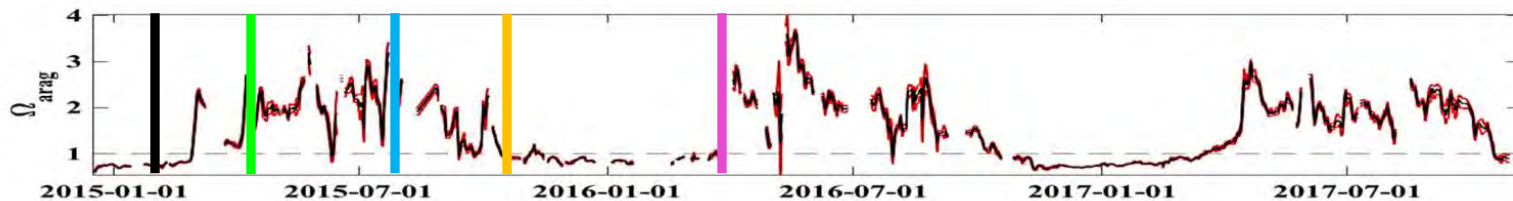
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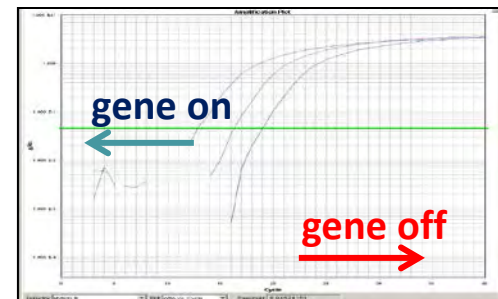
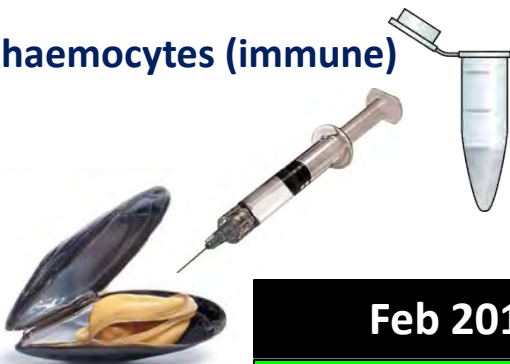
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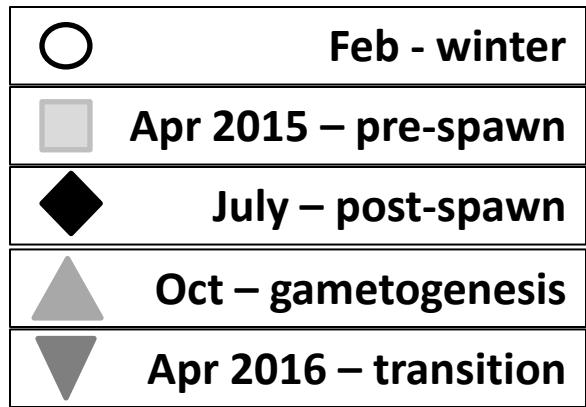
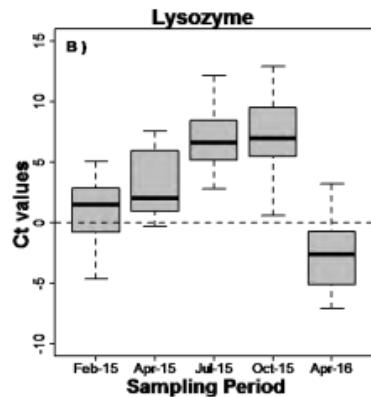
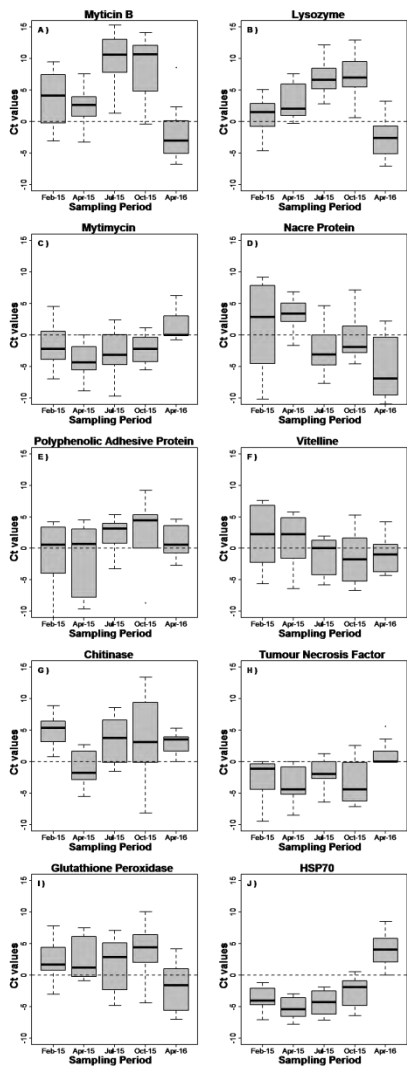
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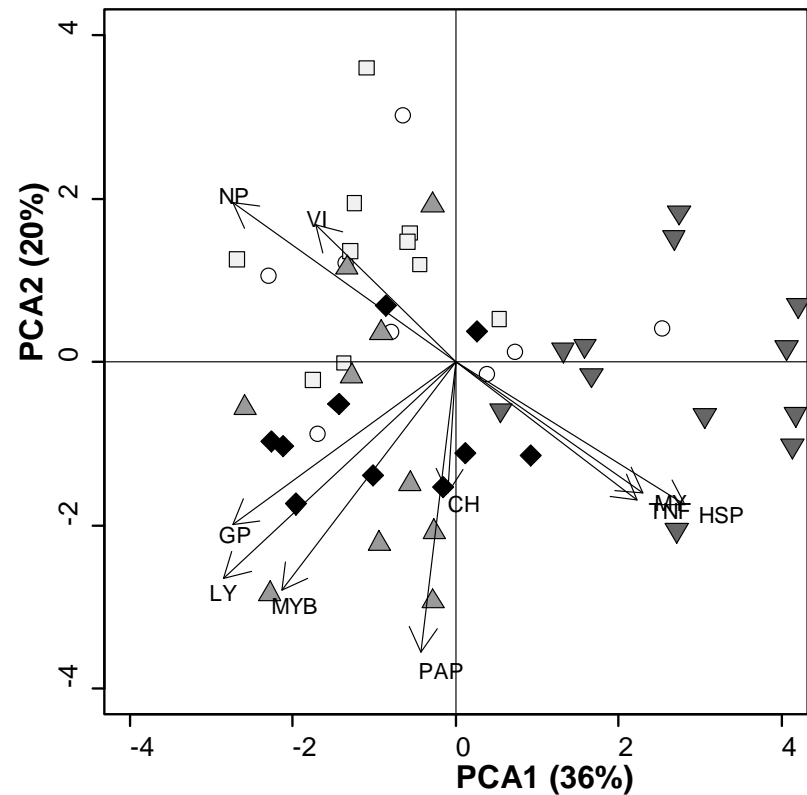
50 genes qPCR

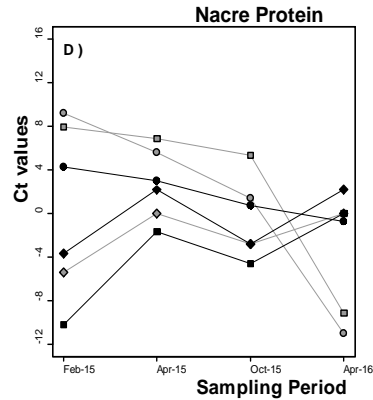
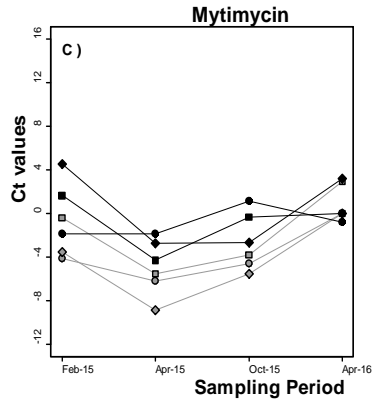
10 genes qPCR

Antibacterial, antifungal, pathogen, antioxidant, stress (general), microbial, shell formation, reproduction, byssus thread

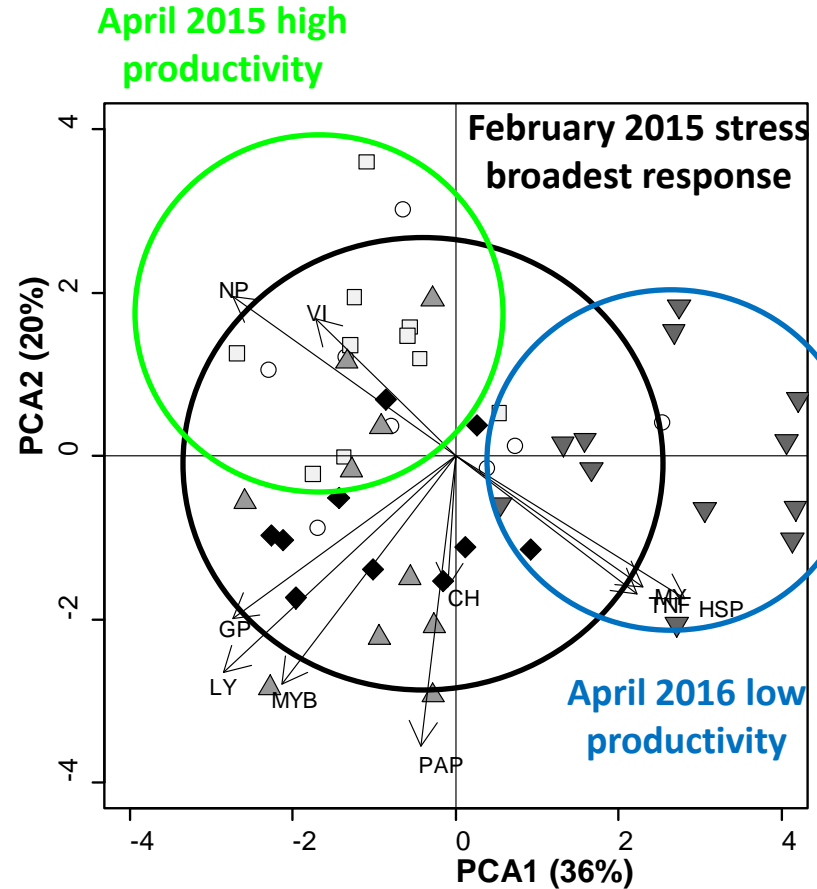


Linear mixed effect model significance over time (months fixed, genes random)

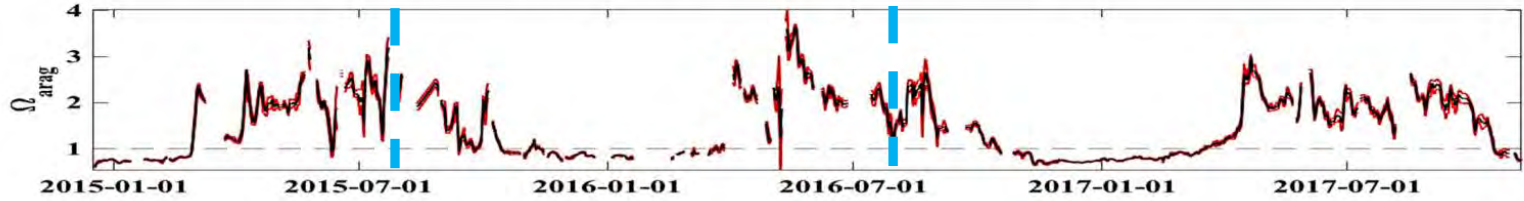




- Individuals had varied responses
- Phenotypic plasticity
- Non-destructive sampling inconsistent
- Different strategies for success? Adaptation?



Shellfish physiology – ‘real-time’ sampling

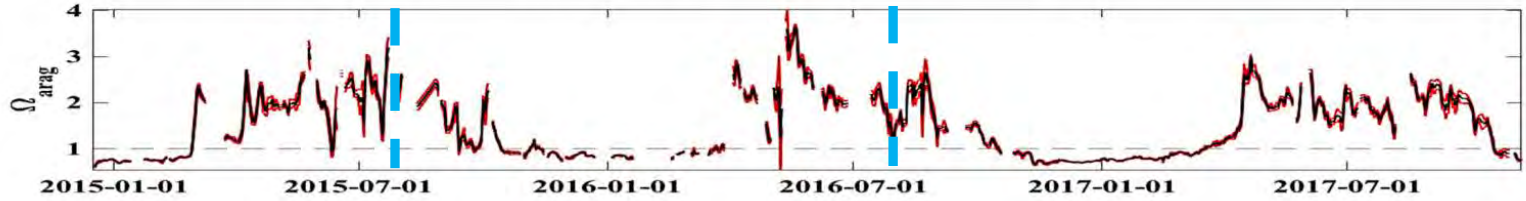


control > 3 Ω_{arag} (July 2015) ‘vs’ corrosive 0.7-0.9 Ω_{arag} (July 2016)



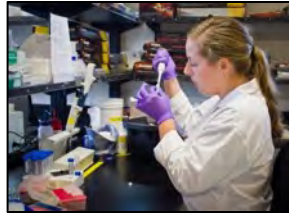
gill (environmental)

Shellfish physiology – ‘real-time’ sampling

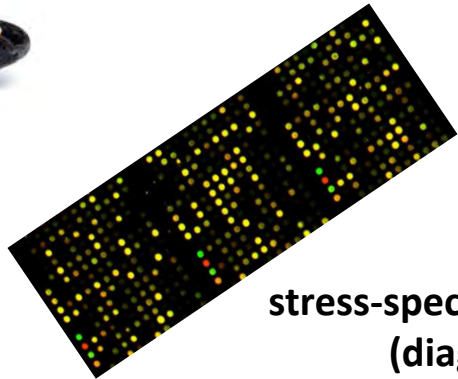


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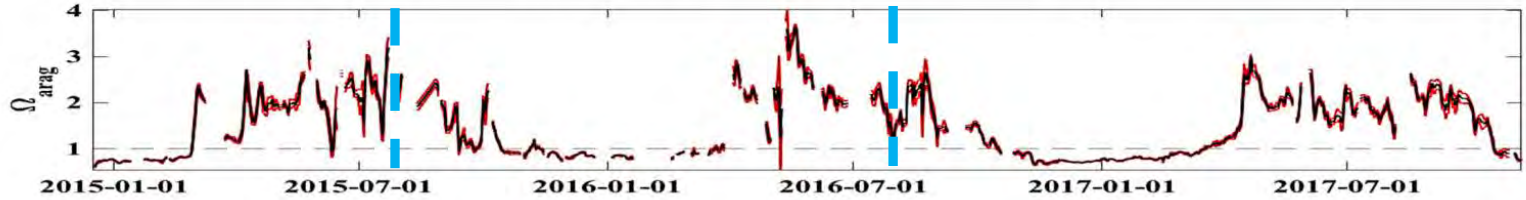


50,000 stress genes
(54% annotation)

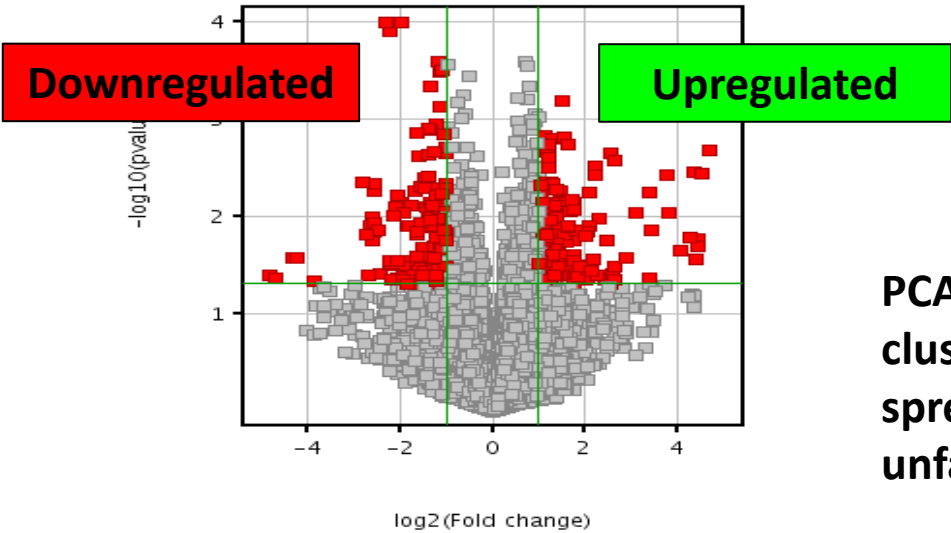


stress-specific microarray
(diagnostic)

Shellfish physiology – ‘real-time’ sampling

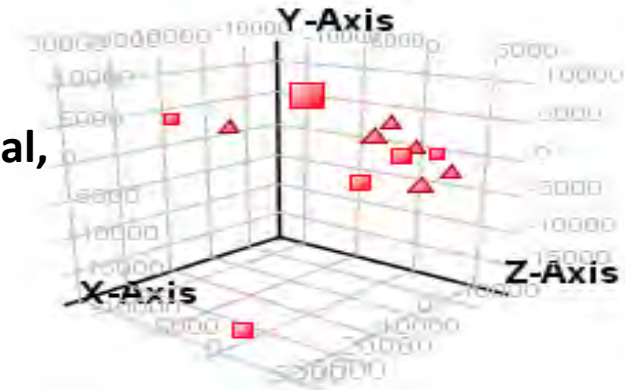


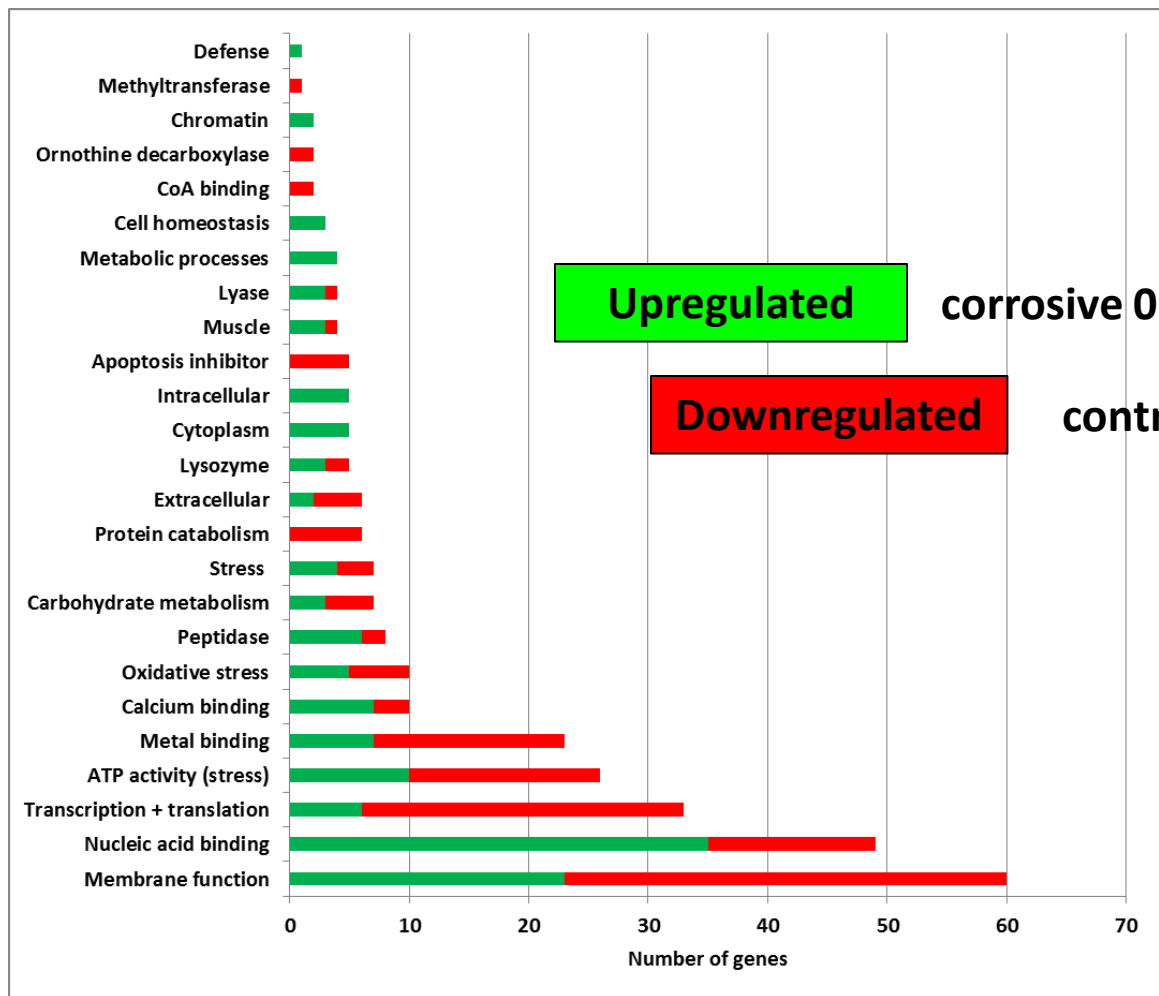
control > 3 Ω_{arag} (July 2015) ‘vs’ corrosive 0.7-0.9 Ω_{arag} (July 2016)



306 genes were significantly differentially expressed (t-test, Fold change >1.5)

PCA showed clustering in optimal, spread in unfavourable





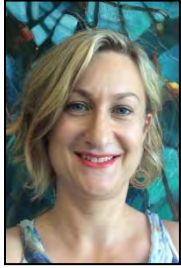
Summary

- Physiological changes were observed with both season and year
- Stress caused a broader gene expression signature
- Individual responses indicated population plasticity responses but were inconsistent over time
- *In situ* corrosive events altered physiological responses, with impacts on translation, transcription, oxidative stress and membrane function

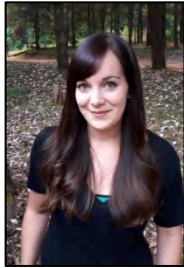
Next steps

- Plankton community analysis
- Gene network analysis
- New challenge laboratories (CO₂ and chemical analysis)
- Multistressor laboratory challenge studies with natural variability
- RNA-Seq analysis oysters, scallops, mussel hybrids
- Coastline population assessment of potential adaptation

Team and Collaborations



Helen Gurney-Smith
(DFO)



Kayla Long
(CSR)



Caitlin Smith
(CSR)



Tamara Brown
(Microthalamia)



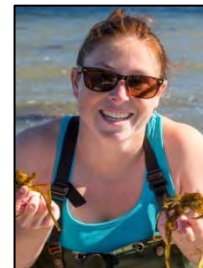
Anne Haegert
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Gregor Reid
(DFO)



Monique Raap
(CSR, UVic)



Brenna Collicutt
(Hakai)



Wiley Evans
(Hakai)

