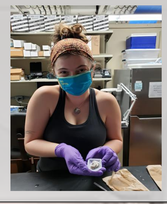
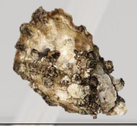


CLIMATE CHANGE CO-STRESSORS AND THEIR EFFECTS ON THE BIOLOGICAL, PHYSIOLOGICAL, AND GENOMIC RESPONSES OF JUVENILE PACIFIC OYSTERS



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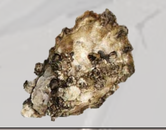
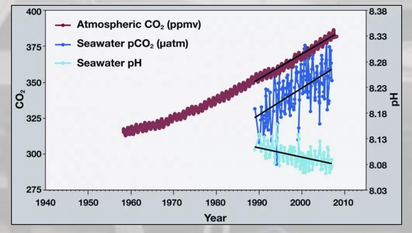
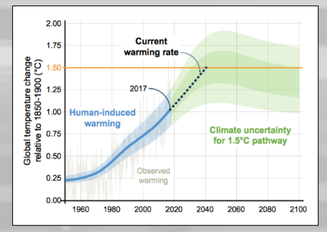


BACKGROUND

Climate change, driven by increasing anthropogenic greenhouse gas emissions, is causing steady increases in global atmospheric and oceanic **temperatures** with coinciding rises in oceanic carbon dioxide (pCO_2) leading to **ocean acidification** (OA). Certain marine animals, including various bivalves (*e.g.* oysters, mussels, clams), have been shown to be negatively impacted by both increasing temperature and OA independently, but rarely has research examined the impacts of both stressors combined. Pacific oyster physiological stress responses set in above 19˚C (Moal et al., 2003, Soletchnik et al., 2003, Samain et al., 2007, McCombie, 2008). The Pacific oyster (*Crassostrea gigas*) is an intertidal species found worldwide and is the most widely cultured oyster in the world (Botta et al., 2020). Oyster production in British Columbia was worth over CAD 67 million between 2016 and 2020 (DFO).



IPCC Projection Data
Ocean Acidification (OA): excess carbon dioxide taken up by the oceans from the atmosphere resulting in elevated pCO_2 and a parallel decline in pH.



NOAA PMEL Carbon Program Data
Warming: rising atmospheric and oceanic temperatures.

Coastal regions like Baynes Sound (BC), with a large shellfish production, are at risk for climate impacts.

OBJECTIVES

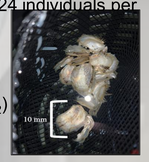
The present research focuses on the impacts of coinciding climate stressors (**warming** and **OA**) on biological (size, shape, and growth), physiological, and genomic responses of juvenile Pacific oysters (*Crassostrea gigas*).

Q1. Which is the bigger threat, **warming** or **OA**?
Q2. Are the impacts cumulative?

EXPERIMENTAL DESIGN

Duration of exposure = 16 weeks in the Fisheries and Oceans Climate Change and Ocean Acidification Laboratory (FOCCOAL) at the Pacific Biological Station in Nanaimo, British Columbia, Canada.

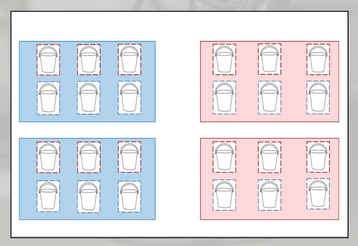
Four treatments in a blocked design, *n*=6 tanks per treatment, N=24 individuals per tank.



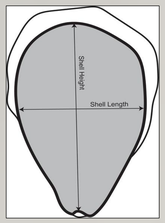
1. 16˚C and 400 ppm (ambient temperature and pCO_2)
2. 16˚C and 1000 ppm (ambient temperature and high pCO_2)
3. 20˚C and 400 ppm (high temperature and ambient pCO_2)
4. 20˚C and 1000 ppm (high temperature and pCO_2)

Experimental ambient pCO_2 (400 ppm) and ambient temperature (16˚C) were determined by the Scripps Keeling Curve and three years of regional summer data (2018-2021) provided by Ocean Networks Canada. Experimental high pCO_2 (1000 ppm) and temperature (20˚C) were determined by 'doomsday' projections for 2100 from the Intergovernmental Panel on Climate Change (IPCC).

Oysters were sampled at regular intervals (bi-monthly/monthly) over the experimental duration to examine shell length, shell height, shell width, condition indices, tissue quality, organ definition. Gene expression samples were also taken for RNA extractions and qPCR analysis.



Legend
Ambient Temperature: 16°C
High Temperature: 20°C
Ambient pCO_2
High pCO_2



Condition Index =

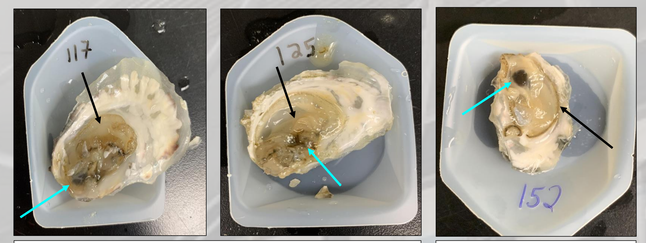
(dry tissue weight * 1000) / dry shell weight

RESULTS AND DISCUSSION

Warming had a more consistent effect on size and condition index than **OA**, with oysters in high temperature treatments displaying lower tissue quality, mantle recession and lower condition index.

Effects of **warming** were most notable after 6 weeks of exposure, suggesting that this may be a critical point in the development of juvenile oysters.

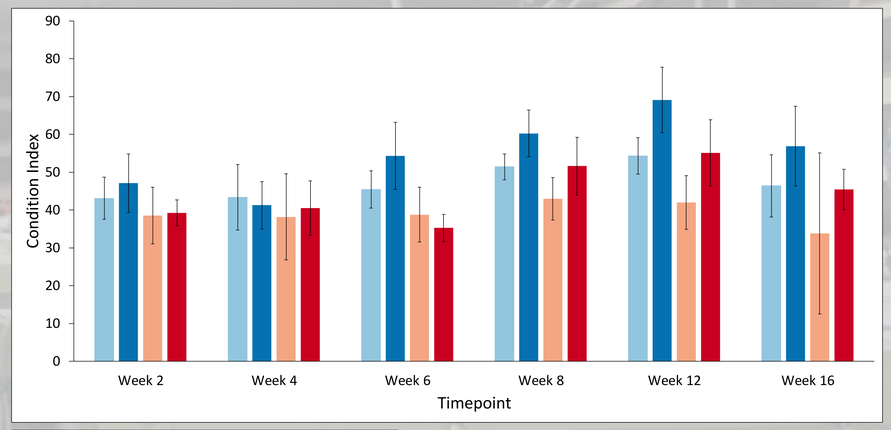
However, after statistical analysis:
Significant differences in temperature were found in only week 6 and 12, and week 12 for pCO_2.



Legend
digestive gland
gill

20˚C TREATMENT
- Poor shell integrity
- Poor tissue quality
- Organs not visually defined
- Weak abductor muscle

16˚C TREATMENT
- Strong shell
- Good tissue quality
- Organs visually defined
- Strong abductor muscle



Legend
16°C/400 ppm (Amb pCO_2)
16°C/1000 ppm (High pCO_2)
20°C/400 ppm (Amb pCO_2)
20°C/1000 ppm (High pCO_2)

Figure 1 shows Condition Index (CI) of experimental oysters sampled at 2, 4, 6, 8, 12, and 16 weeks.

Oysters in the 20˚C treatment had lower average CI values after 6 weeks exposure than those in the 16˚C treatment (ANOVA p<0.01).

Three-way ANOVA statistical analysis was performed using timepoint, temperature, and pCO_2.

Statistical analysis suggest that gene expression in weeks 6 and 12 are worth exploring further.

TAKEAWAYS

- No mortalities throughout the entirety of the experiment
- General CI trends indicated lower CI in high temp and low pCO_2 trials
  - However, significant differences in temperature were found only in week 6 and 12, and week 12 for pCO_2
- Visual observations suggest tissue quality was negatively affected by the high temperature treatment
  - Further tissue analysis and gene expression need to be performed to confirm

FUTURE RESEARCH

BIOMITIGATION MESOCOSM EXPERIMENT (MAY 2023)

Our results from the first experiment indicate that juvenile oysters seem especially sensitive to summer heat stress, and future temperature projections are likely to cause greater stress than current conditions.

Development of temperature mitigation strategies is vital to farmers and stakeholders. Considering this, the next experiment will be investigating potential benefits of integrated multi-trophic aquaculture (IMTA) with Pacific Oysters, sugar kelp (*Saccharina latissima)* and Giant California sea cucumbers (*Apostichopus californicus*).

Sugar kelp from kelp aquaculture farm

Giant California sea cucumber relaxing in palm

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