“Evaluating the impacts of toxic algae *Alexandrium tamarense* and *Heterosigma akashiwo* on juvenile salmon”

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PACIFIC SALMON FOUNDATION

Fisheries and Oceans Canada

Why?

- Harmful algal blooms (HABs) is a significant concern to fishing industry and aquaculture

- In British Columbia (BC) salmon aquaculture industry from HABs totaled ~$16.1 million CAD (2009–2012) - Haigh, Nicola, and Svetlana Esenkulova. "Economic losses to the British Columbia salmon aquaculture industry due to harmful algal blooms, 2009-2012." *PICES Scientific Report* 47 (2014): 2.

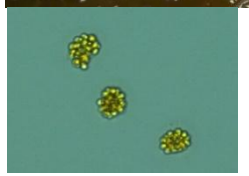
- The main harmful algal species causing salmon losses in BC - *Heterosigma* responsible for ~65% of fish-killing blooms and ~90% of high-severity events.

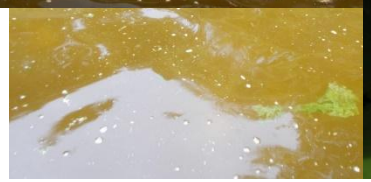
- *Heterosigma* blooms have been linked to poor survival of wild BC salmon (Rensel et al., 2010) + Cohen Commission

Why?

Evidence (histology, elevated post pit-tagging mort) that wild juvenile salmon might be affected by HABs similarly to farmed salmon (Esenkulova et al., 2022)

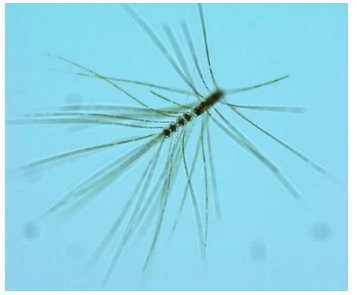


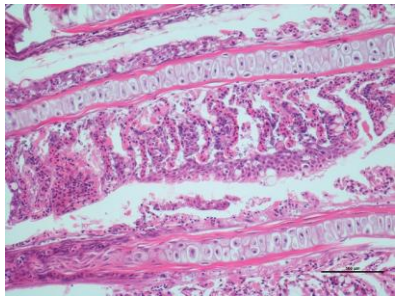




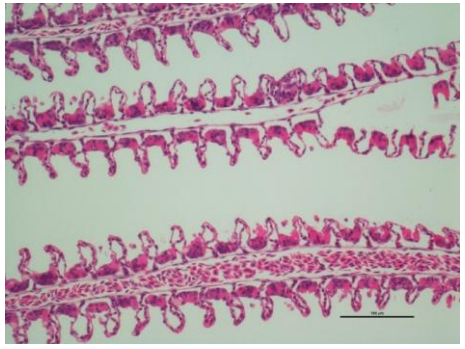


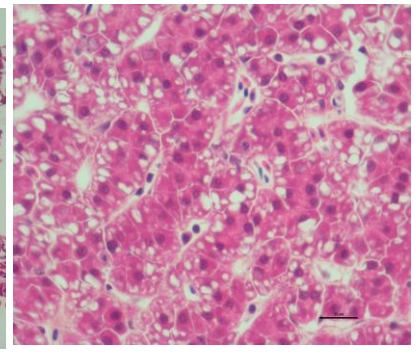
Juvenile salmon in Cowichan Bay appeared stressed during 2014 Heterosigma akashiwo bloom (lethargic behavior in the net, **25 fold increase in post-pit tagging mortality**)





Damaged gills of juvenile salmon in Cowichan Bay **after mechanically harmful bloom**





Liver and gill damage after toxic bloom

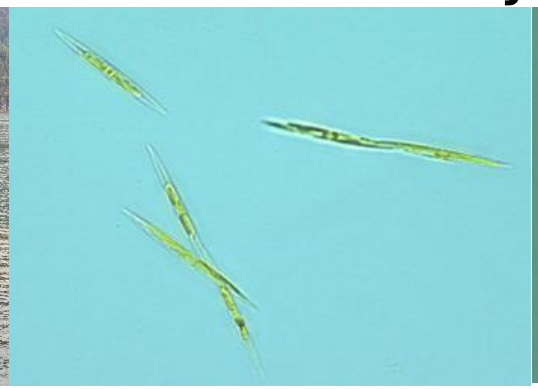
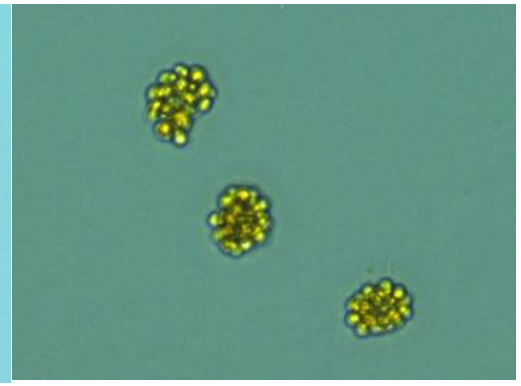
Why?

Harmful algae are very common and often abundant in SoG

(Esenkulova et al., 2024)

- HAB taxa are persistent and recurrent in the Strait of Georgia. Implication - HABs represent a chronic baseline risk, not rare events.
- Clear interannual variability, including “event years”. The dataset shows strong year-to-year differences in abundance and dominance of HAB taxa.
- A major Heterosigma bloom in 2018 was documented in the dataset. This event coincided with reported major farmed salmon mortality.



Critical gap - MECHANISM

Need to move from correlation to causation

- Controlled exposure is needed to confirm direct cause-and-effect
- Contribute to understanding of mechanisms of toxicity and other effects

Study - how juvenile Chinook respond across behaviour, tissues, toxins, to controlled exposure to harmful algae

Fish killing algae in British Columbia

Heterosigma akashiwo

***Alexandrium* spp.**

C. convolutus and *C. concavicornis*

Cochlodinium fulvescens

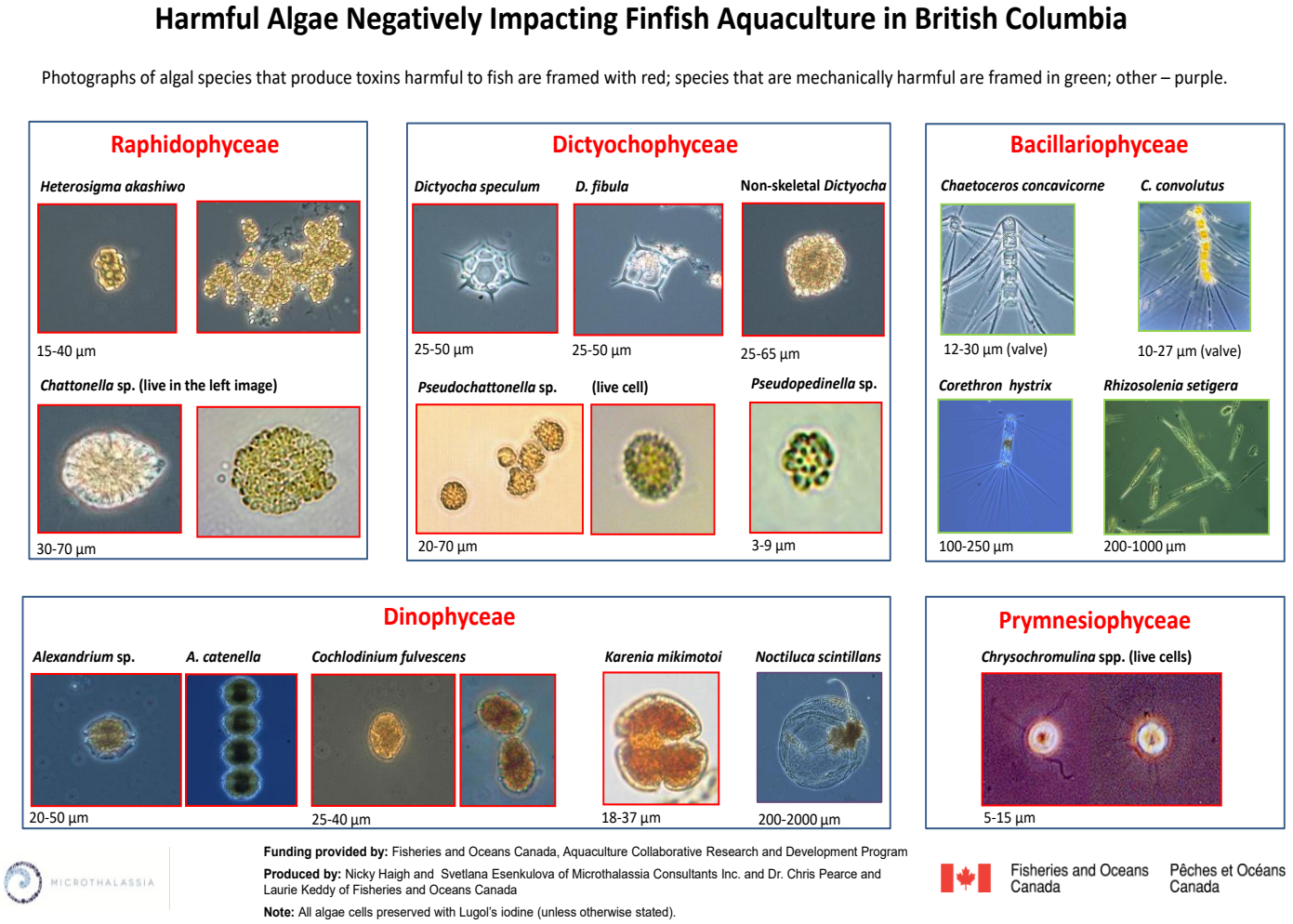
Dictyocha spp.

Dinophysis spp.

Noctiluca scintillans

Rhizosolenia setigera

Pseudo-nitzschia spp.



Esenkulova, S., Sutherland, B.J.G., Tabata, A., Nicola Haigh, N., Pearce, C.M., Miller, K.M., 2020: **Comparing metabarcoding and morphological approaches to identify phytoplankton taxa associated with harmful algal blooms**. Facets 5: 784-811

Challenge study design





Juvenile chinook (~65 gr) in nine x 400L tanks (20 per tank)

3 Alexandrium, 3 Heterosigma, 3 control (no algae)

24 hours, static, aerated, two 50% water exchange (8 and 16h)

Sampling: Water quality (T, S, DO, pH, total ammonia nitrogen), algae concentrations, toxins in Alexandrium tanks, carbonate water chemistry, bacterial community (16S), videos

Fish samples at 12h and 24 hours: tissues for histological analysis, toxins in gills/liver, other (genomics)

Results

- Ethics, AUPs, 3 pilots completed
- Thousands of liters grown
- Media - enriched natural seawater medium (Harrison et al., 1980)
- ~28–29 ppt, 16–17°C
- Continuous (24 h) light 40 µmol photons m^{-2} s^{-1}
- Grown for 15 days
- Cultures cell per mL ~5,000 Alexandrium - post-peak, ~120,000 Heterosigma - active growth

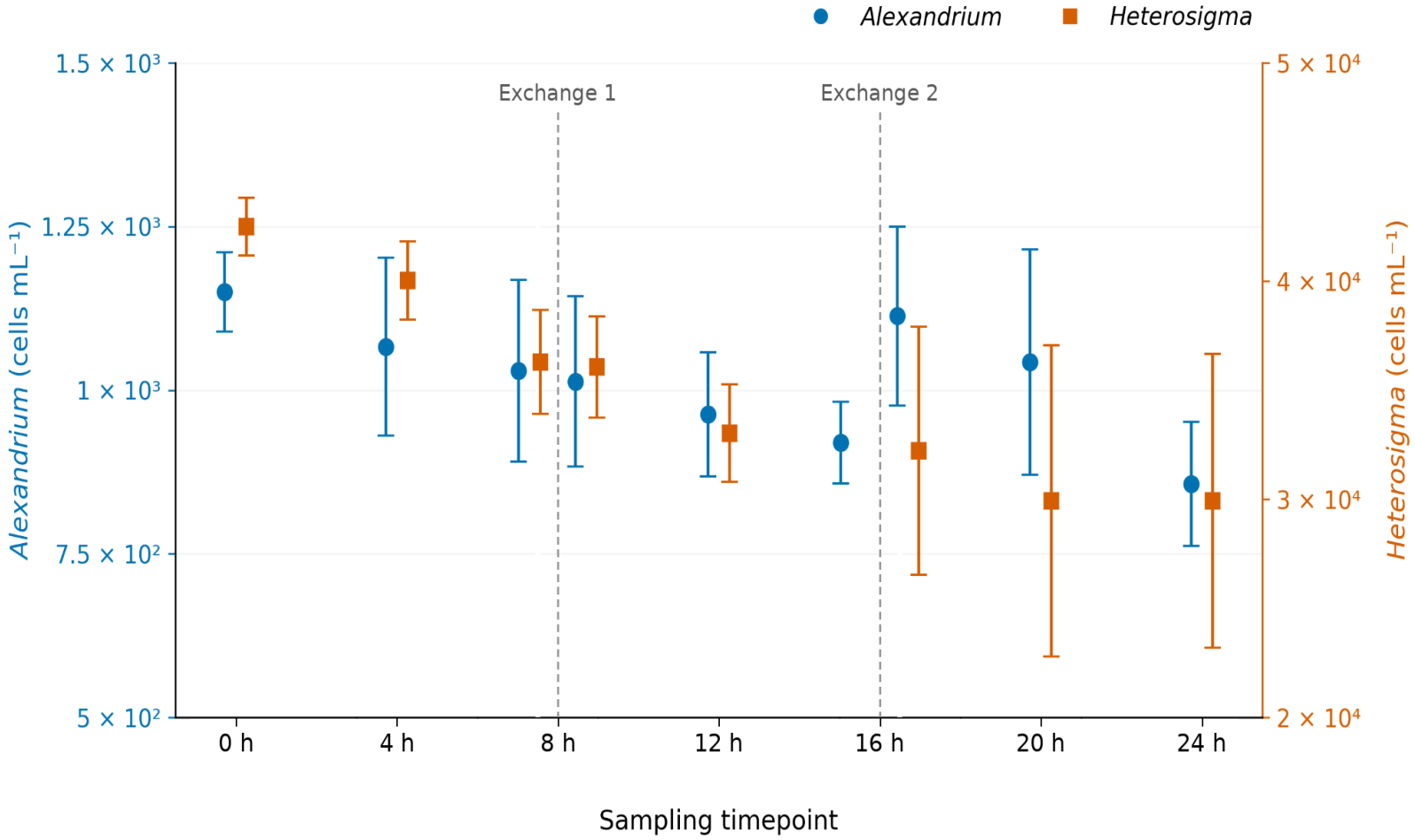
Exposure:

- In 400L tanks - 300L of sweater, switched to static
- Alexandrium treatment – 60 L
- Heterosigma – 110 L



Alexandrium tamarense Bag, 2026

Results - algae



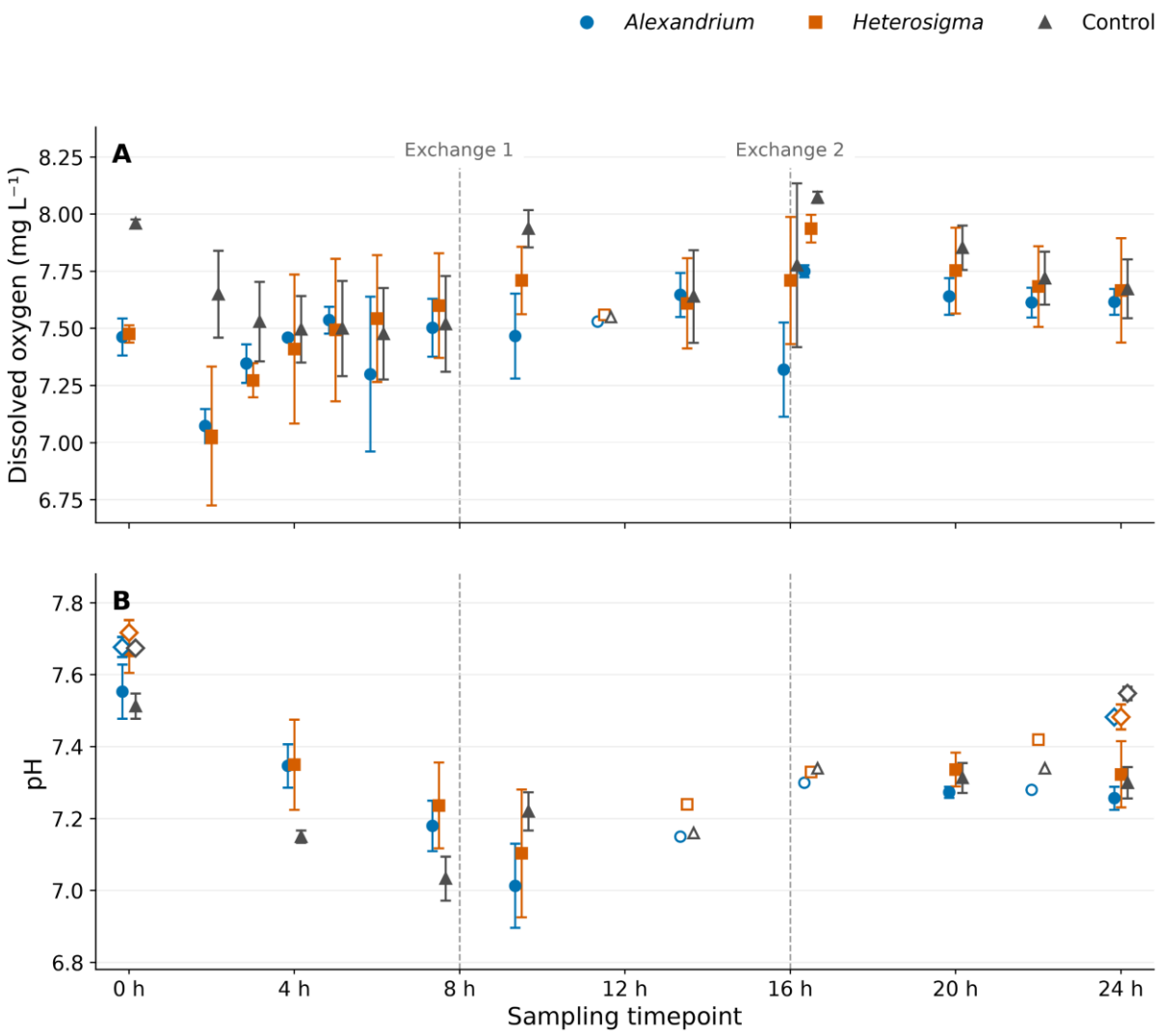
Starting mean across treatment:
~1,000 cells mL^{-1} for Alexandrium
~40,000 cells mL^{-1} for Heterosigma

Trying to encourage mixing/prevent cell settling with coarse bubbles

Slow decline overtime. Very approximate ~10% every 8 hours

the largest mean decline:
overnight for Alexandrium
the first 8 h for Heterosigma

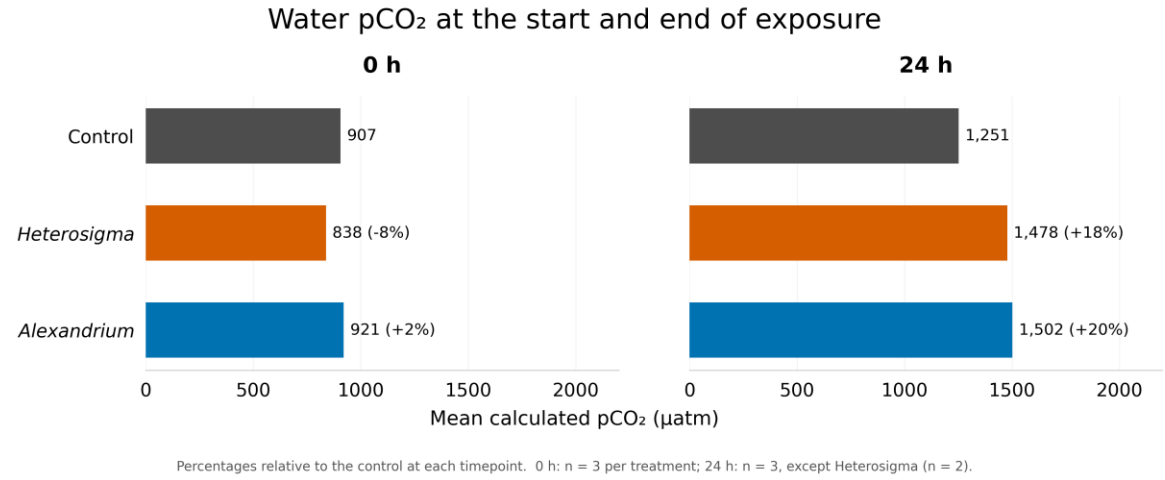
Results – water quality



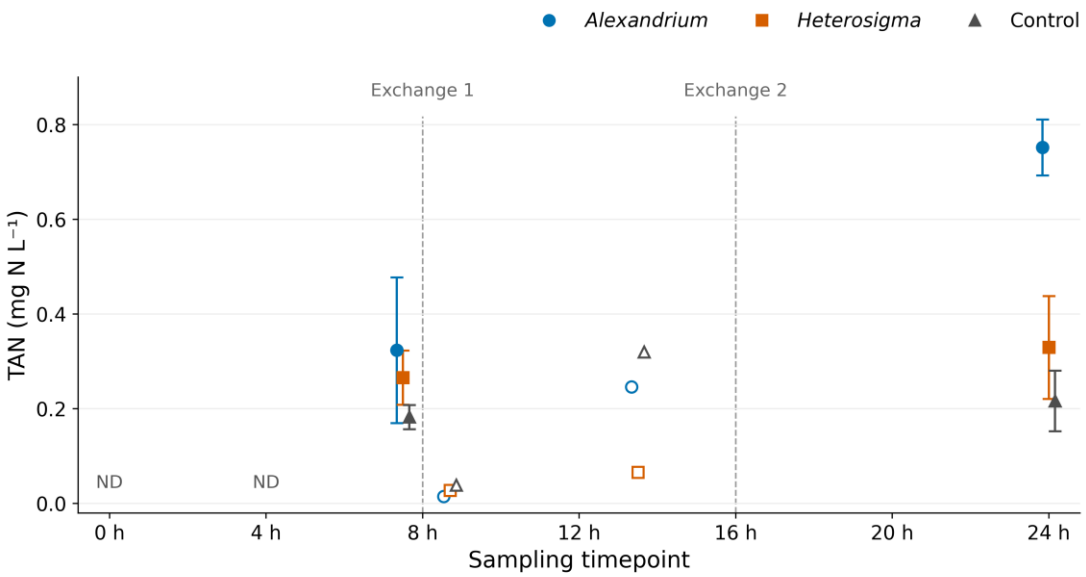
Stable: Temperature ~16 C, Salinity - 28-29 ppt

Varied: **Dissolved oxygen** 6.68 to 8.19 mg L^{-1} declined in all treatments, aeration was increased

pH declined during the daytime, recovered overnight.
Final mean pCO_2 was ~20% higher in *Alexandrium* and ~18% higher in *Heterosigma* than in controls.



Total Ammonia Nitrogen (TAN)



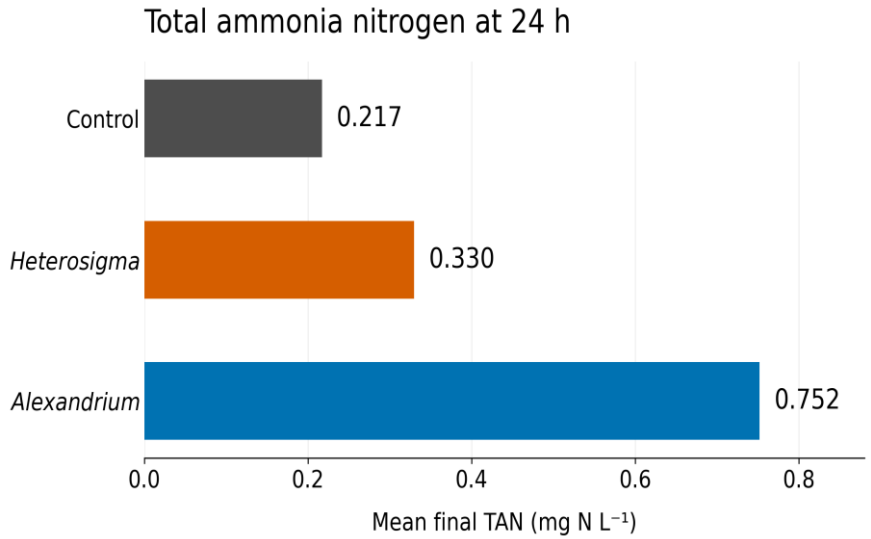
Fish excretes ammonia
Important to monitor during fish exposures

TAN was initially undetected and accumulated during exposure, consistent with metabolic waste production

TAN within safe limits
Calculated un-ionized toxic ammonia (NH_3) within safe limits
0.0006 - 0.0035 mg NH_3-N L^{-1} < (0.0125 mg)

At 24 h, mean TAN concentrations were 3.5 times the control mean in *Alexandrium* and 1.5 times the control mean in *Heterosigma*.

Greater TAN due to fish excretion???

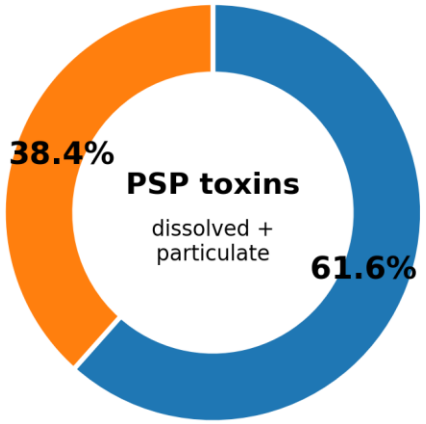


Results - toxins



Total mean PSP - 1,418.8 ng/L. Comparable with measurements from the field e.g. highest in BC reported from Barkley Sound 4,000 ng/L PSP (Ross and Mueller, 2024).

Predominantly dcSTX (decarbamoylsaxitoxin) ~70%, followed by dcNEO ~20%, and other



DISSOLVED · 61.6%

Toxins in the surrounding water that pass through the filter

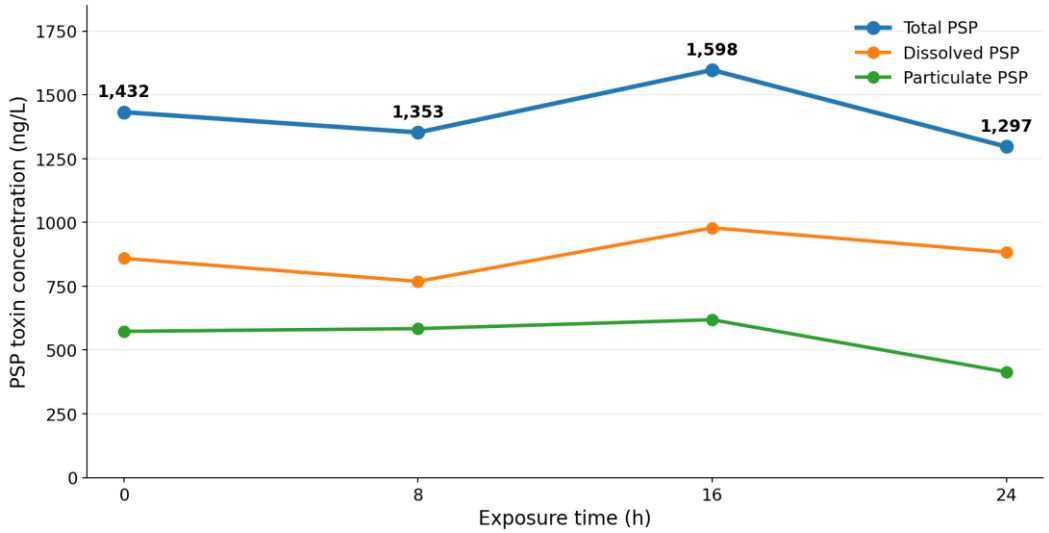
PARTICULATE · 38.4%

Toxins associated with algal cells or other particles retained on the filter

No PSP toxins in gills and liver after 24 hour exposure to the bloom conditions!

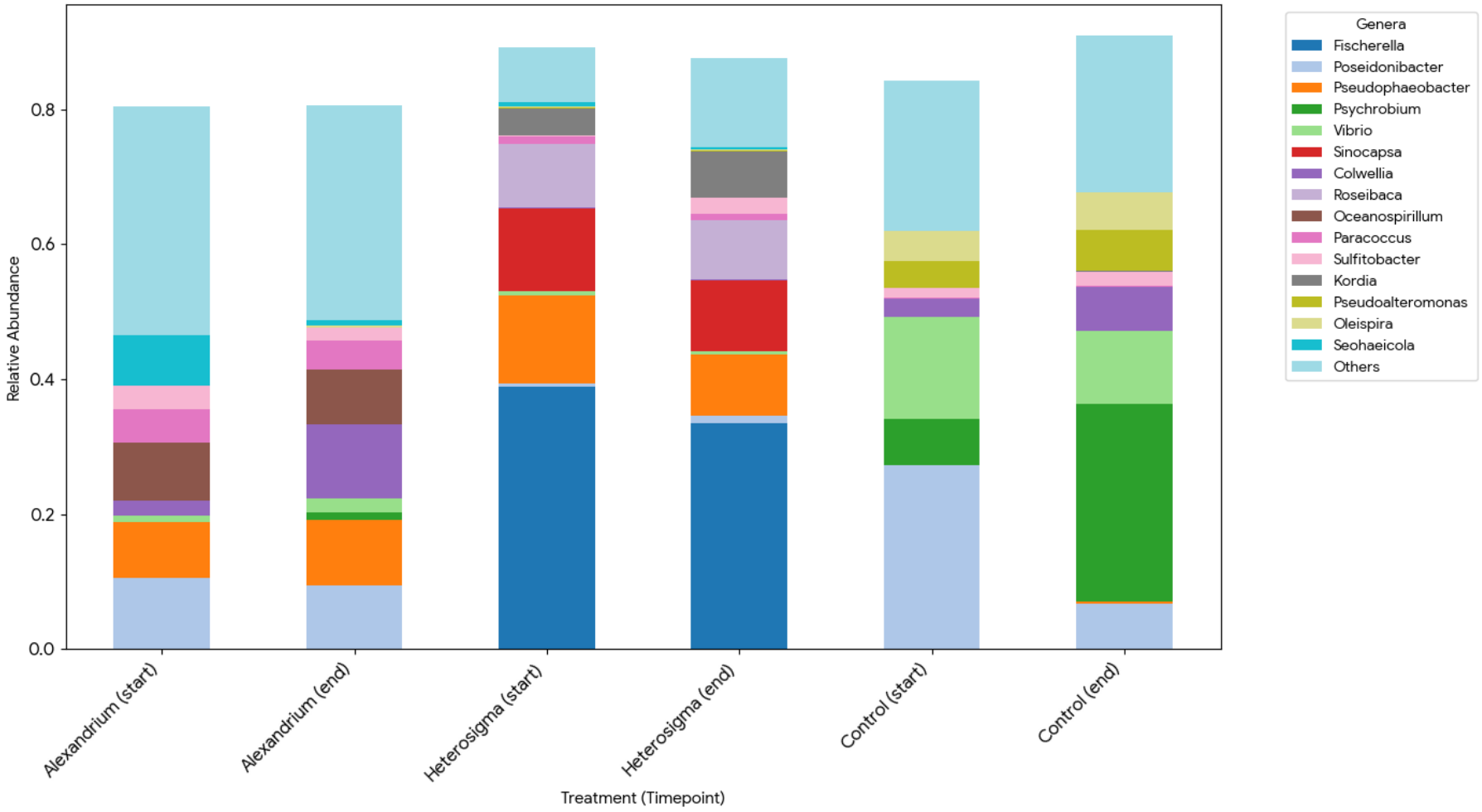
PSP concentrations peaked at 16 h

PSP concentrations did not consistently track algal cell abundance but all were the lowest at 24h



Mean of paired tank samples (0 h: n = 2; 8–24 h: n = 3).
Samples at 8 and 16 h were taken before water exchanges.

Results – microbial community



Start largest contributors:

<u>Alexandrium:</u>

Poseidonibacter (~10%)

Oceanospirillum (~9%)

Pseudophaeobacter (~8%)

<u>Heterosigma:</u>

Fischerella (~39%)

Pseudophaeobacter (~13%)

<u>Control:</u>

Poseidonibacter (~27%)

Vibrio (~15%)

24 h largest progression:

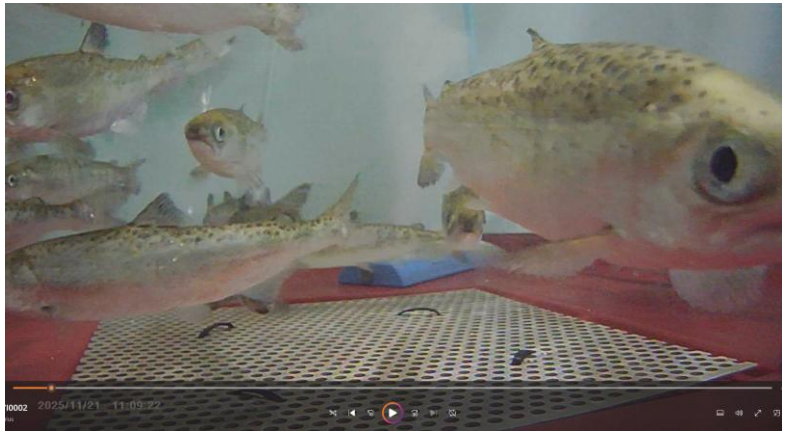
Colwellia in *Alexandrium* ⬆

Kordia in *Heterosigma* ⬆

Psychrobium in controls ⬆







Alexandrium

Heterosigma

Control

Results - behavior



- Video available, not analyzed
- BORIS program
- Alexandrium and control – good visibility
- Heterosigma – bad visibility

Preliminary result: salmon in Heterosigma treatment swim less

Summary:

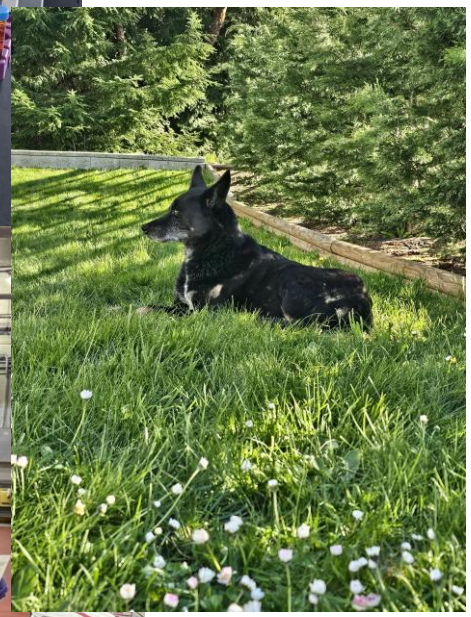
- A first-of-its-kind multi-endpoint HAB-salmon challenge
- The results provide a strong experimental foundation
- RNA-seq results are particularly promising
- Strong foundation for mechanistic studies

study possible due to multidisciplinary team!









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