



Effect of temperature on chlorine as BW Treatment to eliminate freshwater phytoplankton

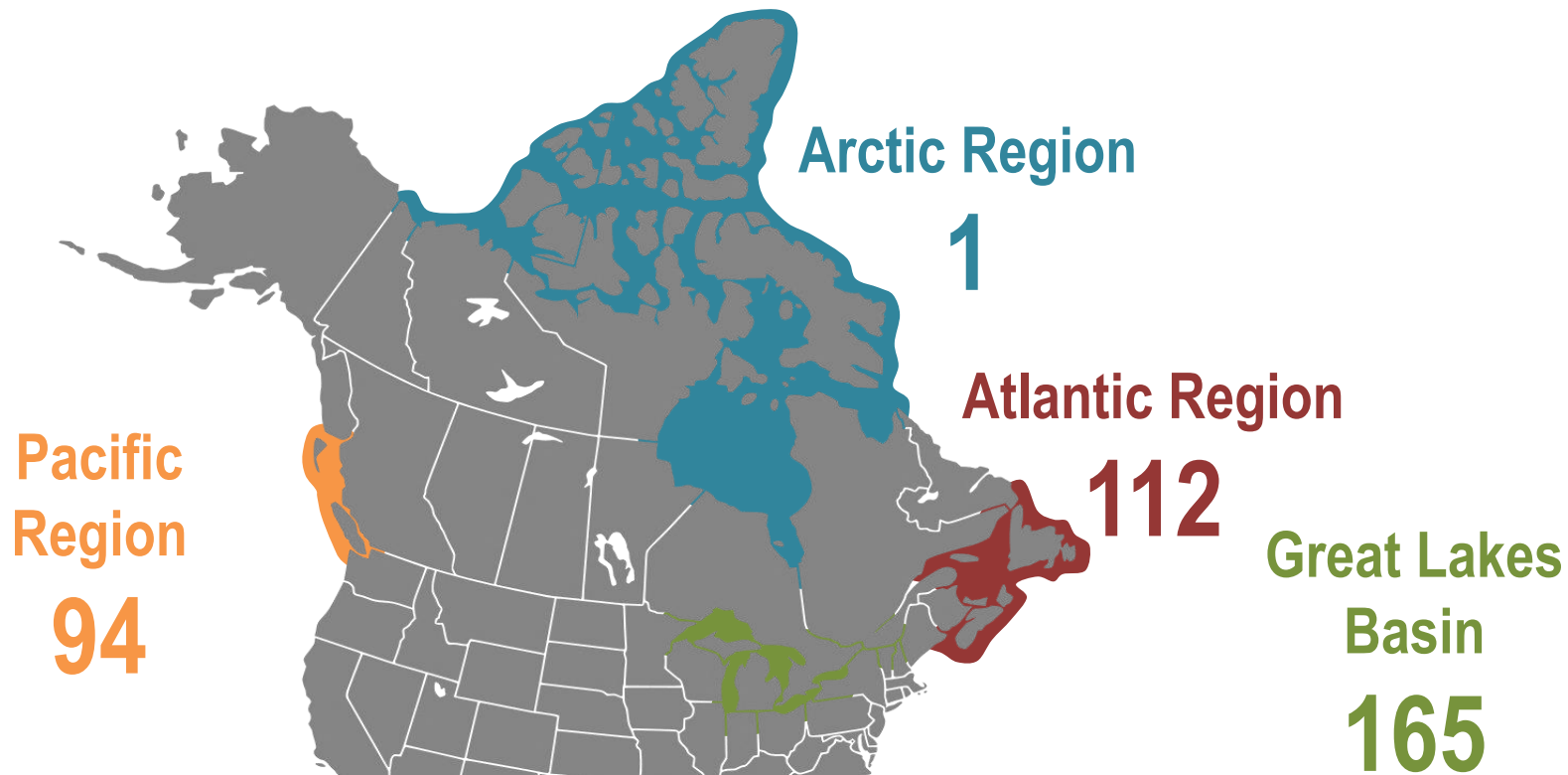
Casas-Monroy O, J Vanden Byllaardt, J Bradie, and SA Bailey. 2017.

Great Lakes Laboratory for Fisheries and Aquatic Sciences
Fisheries and Oceans Canada





Status of invasions in Canada






Movement of commercial ships: new routes



Source: University of Bremen - Polar View



Introduction

- **With the entry into force** (last September) of the “International Convention for the Control and Management of Ship’s Ballast Water and Sediments”, ships are required to install Ballast Water Management Systems (BWMS) on board
- Rationale for BWMS:
 - Quantitative discharge standard 
 - Less influence of weather, ship structure, crew
 - More uniform protection across habitat types



(Carlton, 1985; Olenin et al., 2000; Ruiz et al., 2000; Chan et al. 2012)



Ballast Water Management Systems (BWMS)

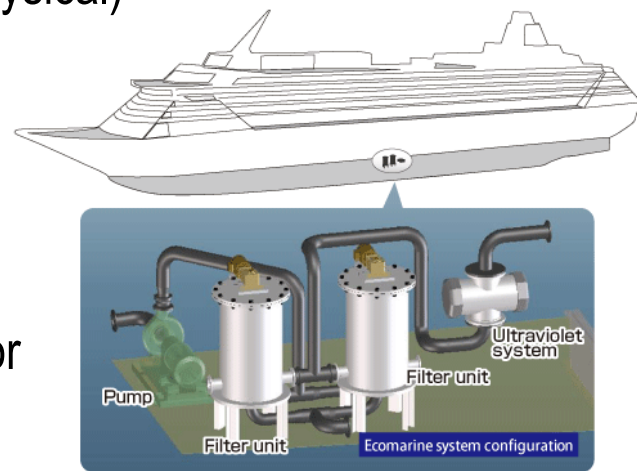
There are a large number of BWMS on the market using technologies such as:

- Filtration, hydrocyclone, coagulant (separation)
- Chemical Disinfection (biocides)
- Ultra-violet treatment, De-oxygenation, ultrasonic, heat (Physical)

All treatment systems are subject to approval through the IMO
(and also the U.S. if being used there)

However, Type Approval does not equal global efficacy:

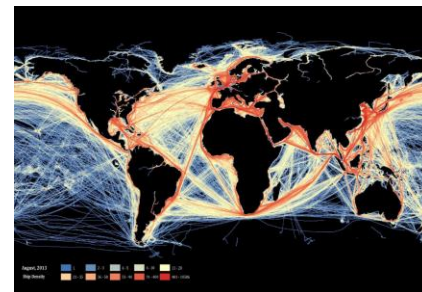
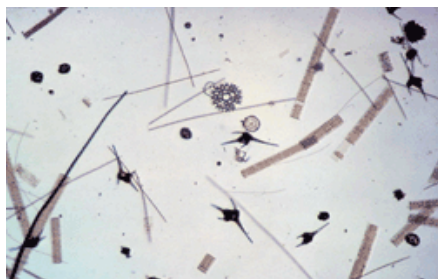
- Complex systems subject to malfunction or operator error
- Few systems tested in cold/hot, turbid or fresh water





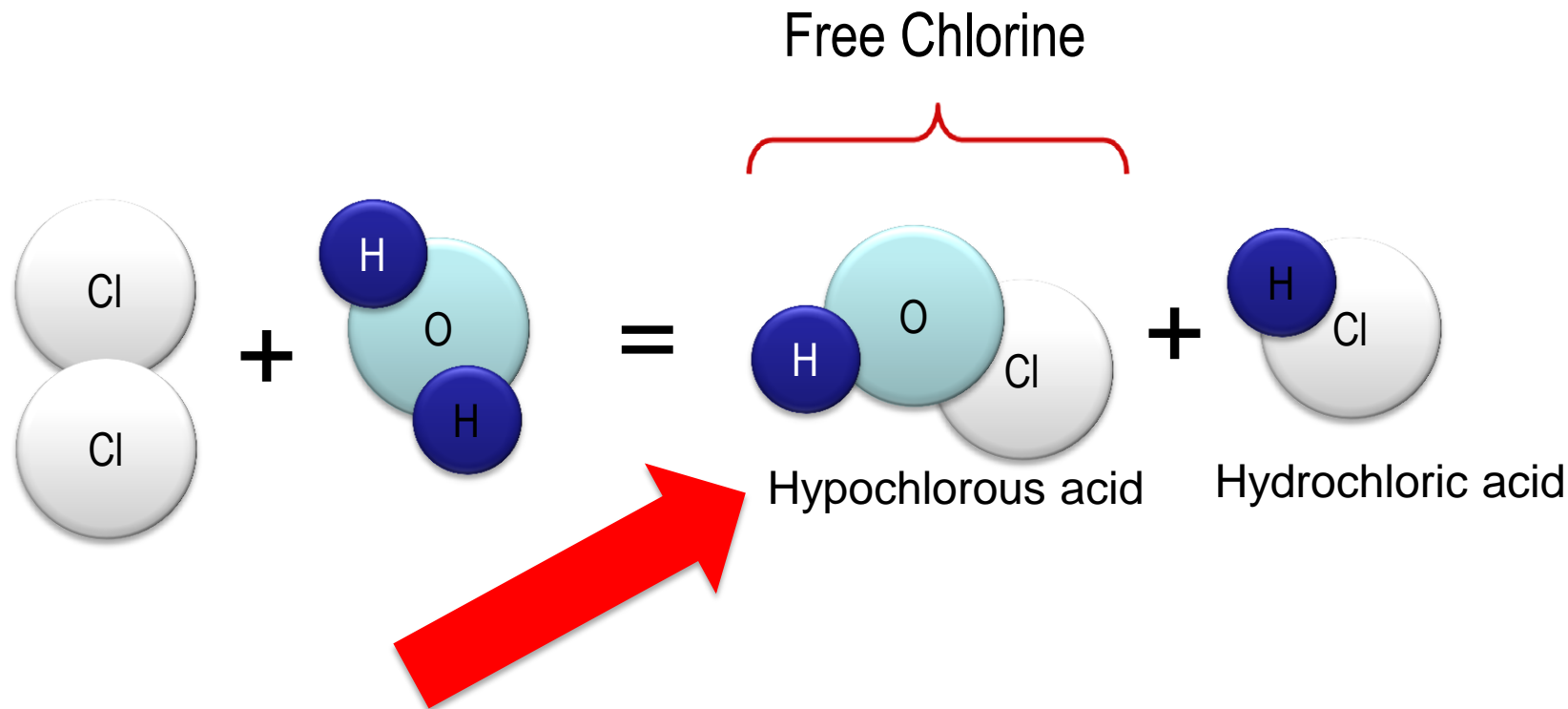
Objectives

- Examine efficacy of chlorine against freshwater phytoplankton communities from Hamilton Harbour under extreme temperature conditions
- Determine if chlorine ballast water treatment would provide greater protection at low temperatures than high temperatures
- Examine if phytoplankton communities behave differently or are more sensitive to treatment at different temperatures



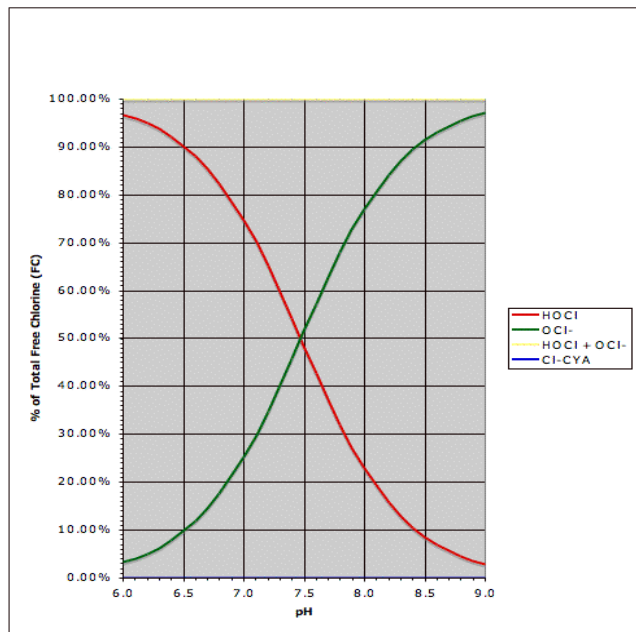


Testing chlorine as biocide





Testing chlorine as biocide



Fundamental actions:

- Alteration of cell permeability
- Colloidal nature of protoplasm
- Organism DNA or RNA,
- Cell wall damage and by inhibition of enzyme activity (Tsolaki and Diamadopoulos, 2009).

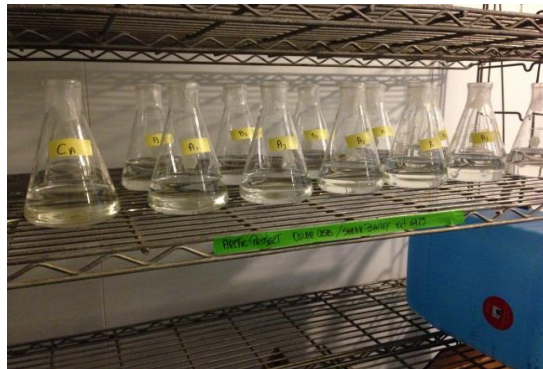
HOCl (Hypochlorous acid)



H + OCl (Hypochlorite ion)

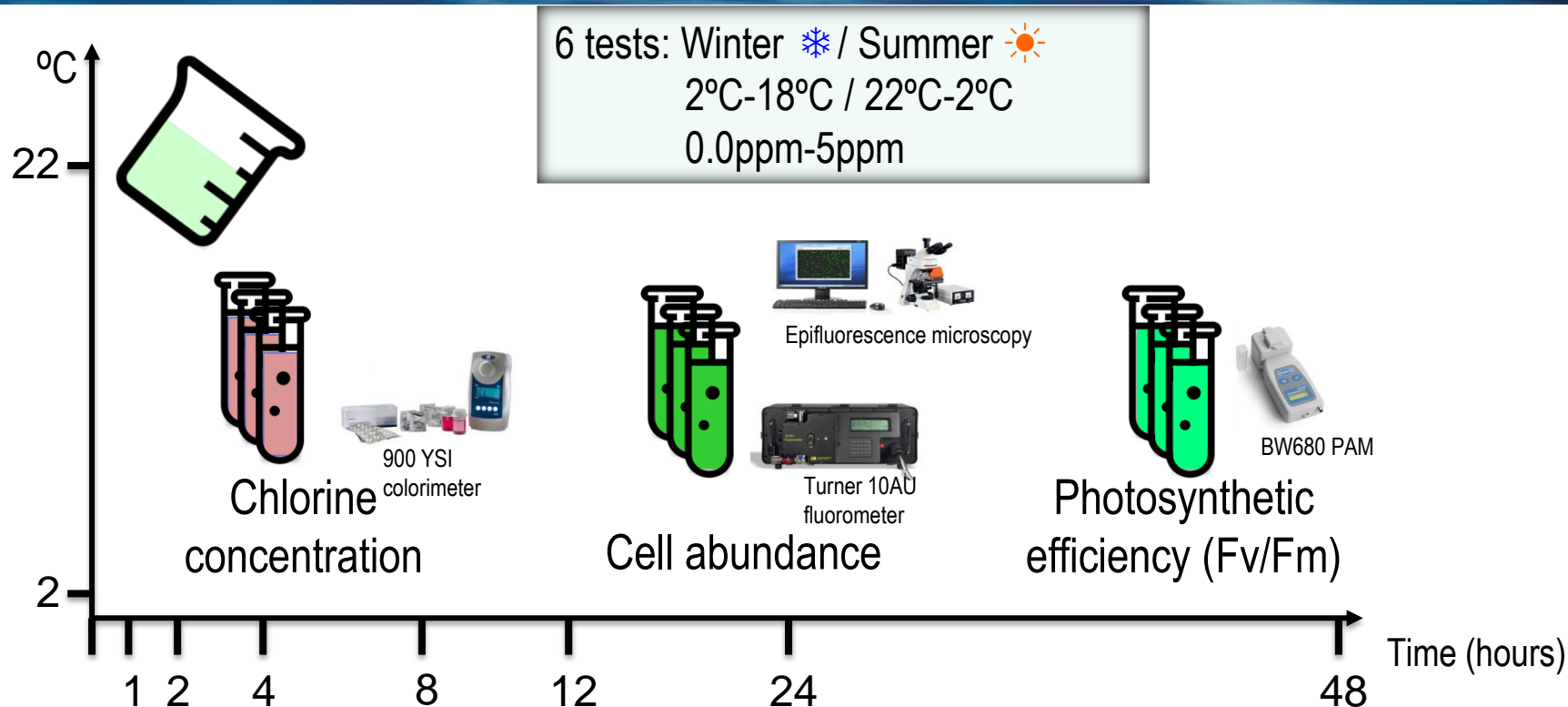


Methods for a bench scale test...



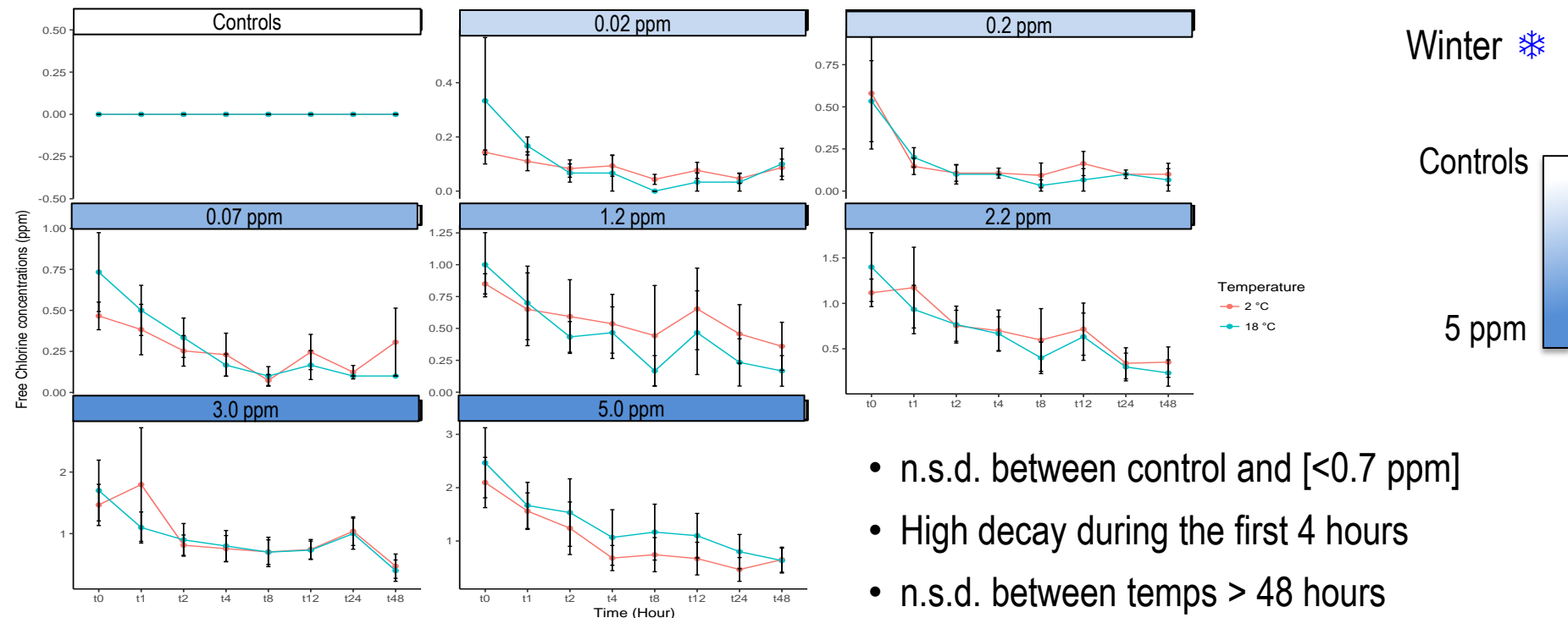


Methods for a bench scale test...





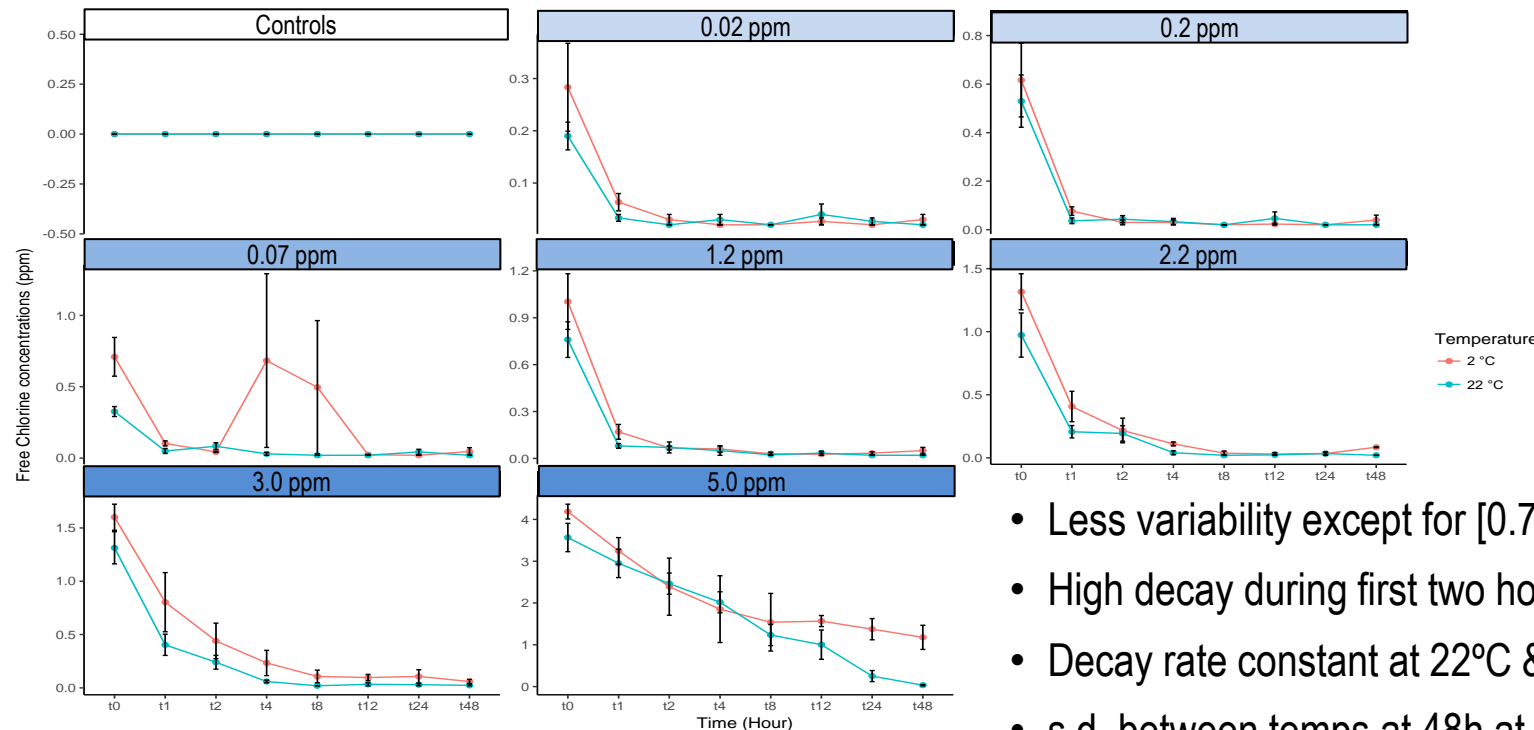
Results – Chlorine concentrations



- n.s.d. between control and [<0.7 ppm]
- High decay during the first 4 hours
- n.s.d. between temps > 48 hours



Results – Chlorine concentrations



Summer ☀

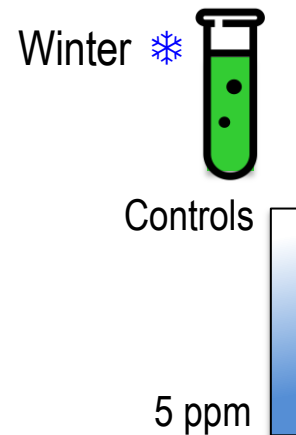
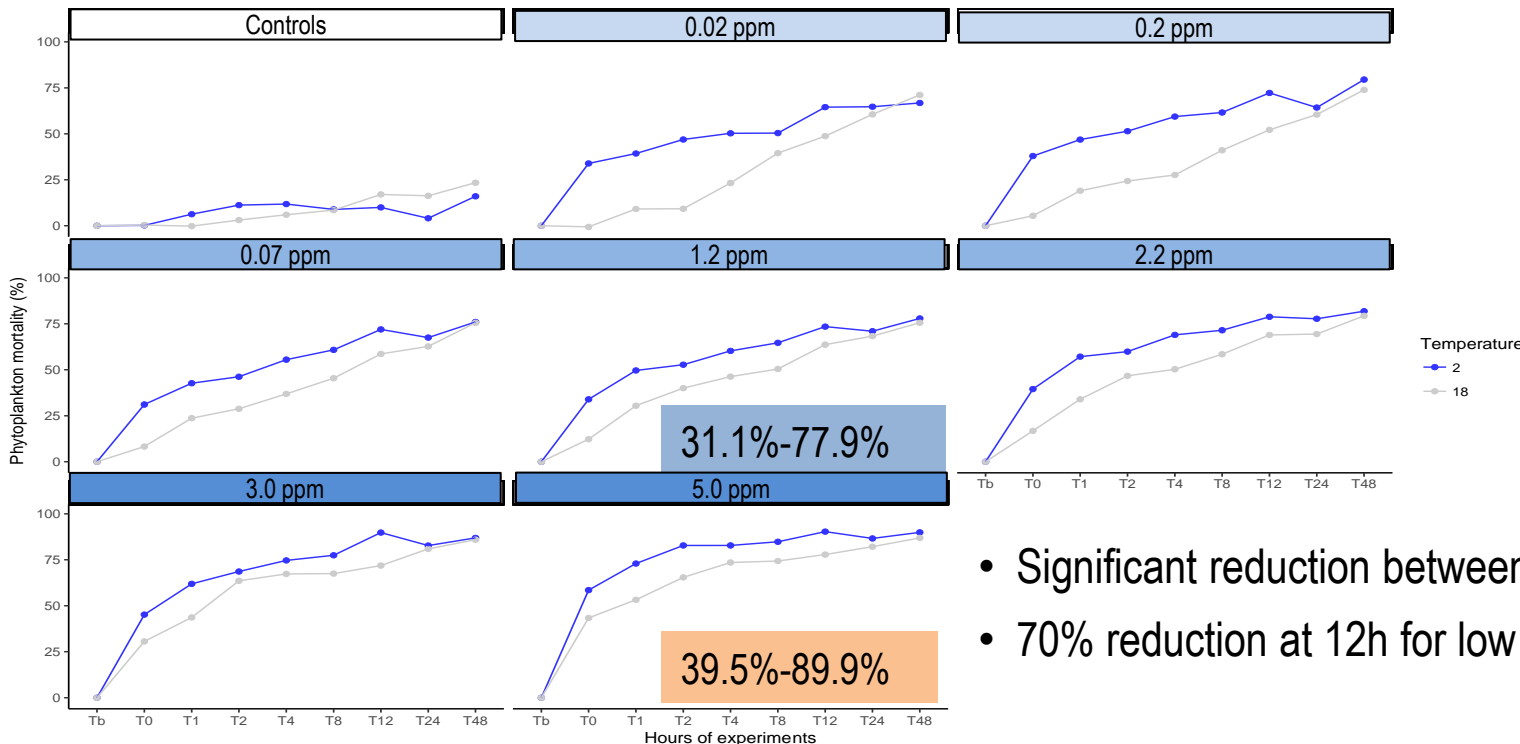
Controls

5 ppm

- Less variability except for [0.7 ppm]
- High decay during first two hours
- Decay rate constant at 22°C & [5 ppm] !
- s.d. between temps at 48h at [5ppm]



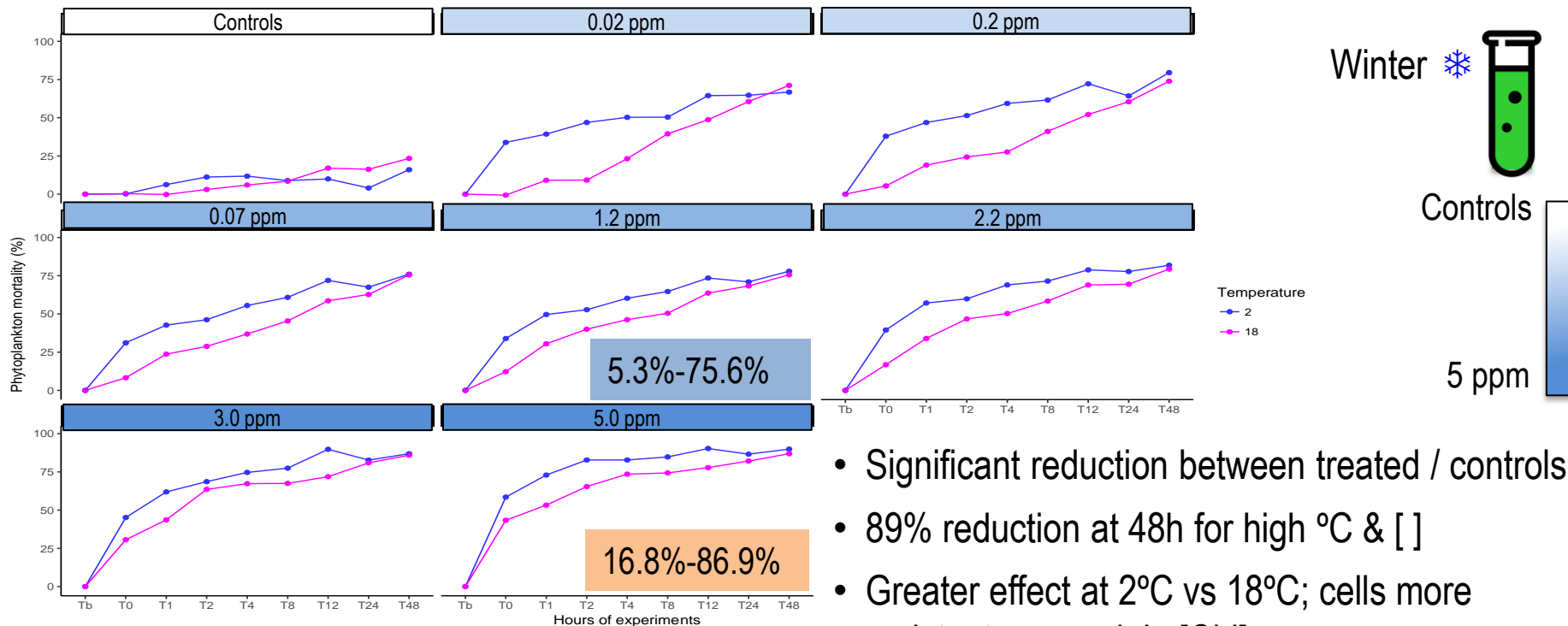
Results – Phytoplankton abundance



- Significant reduction between treated / controls
- 70% reduction at 12h for low °C & []



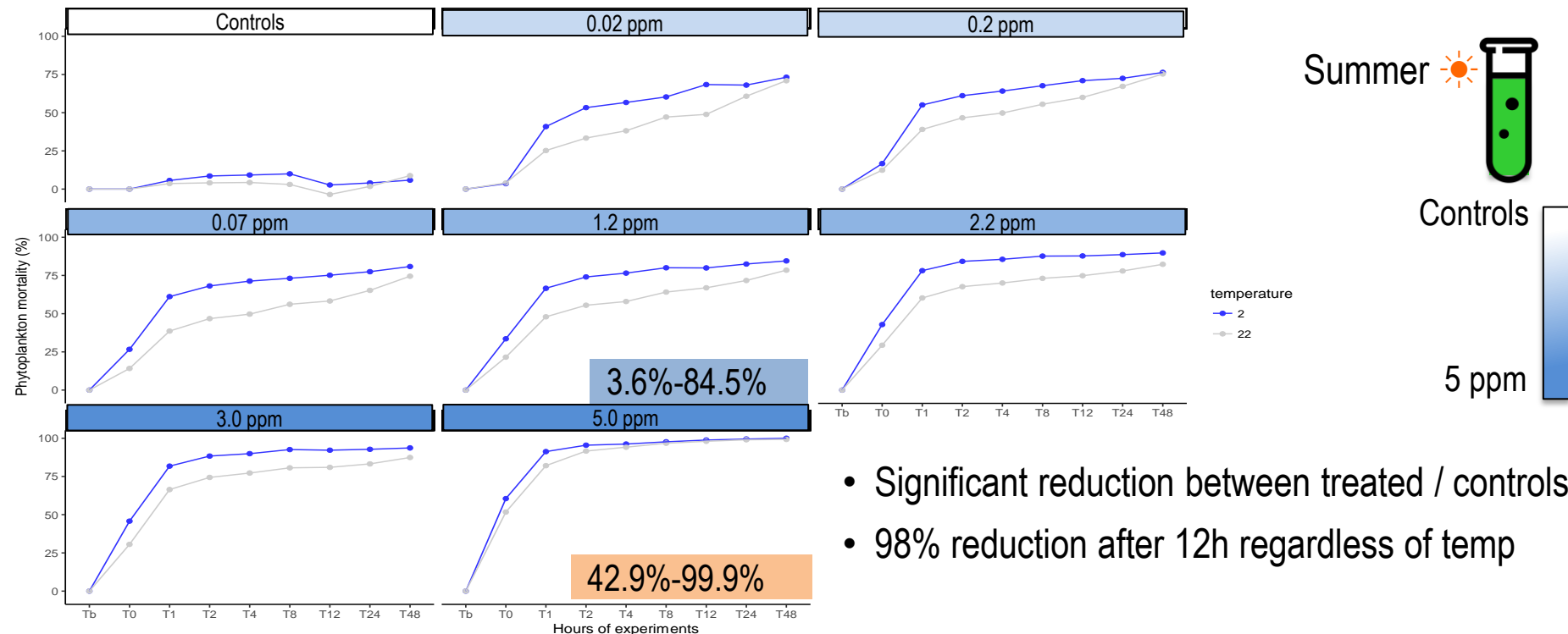
Results – Phytoplankton abundance



- Significant reduction between treated / controls
- 89% reduction at 48h for high °C & []
- Greater effect at 2°C vs 18°C; cells more resistant => n.s.d. in [Chl]



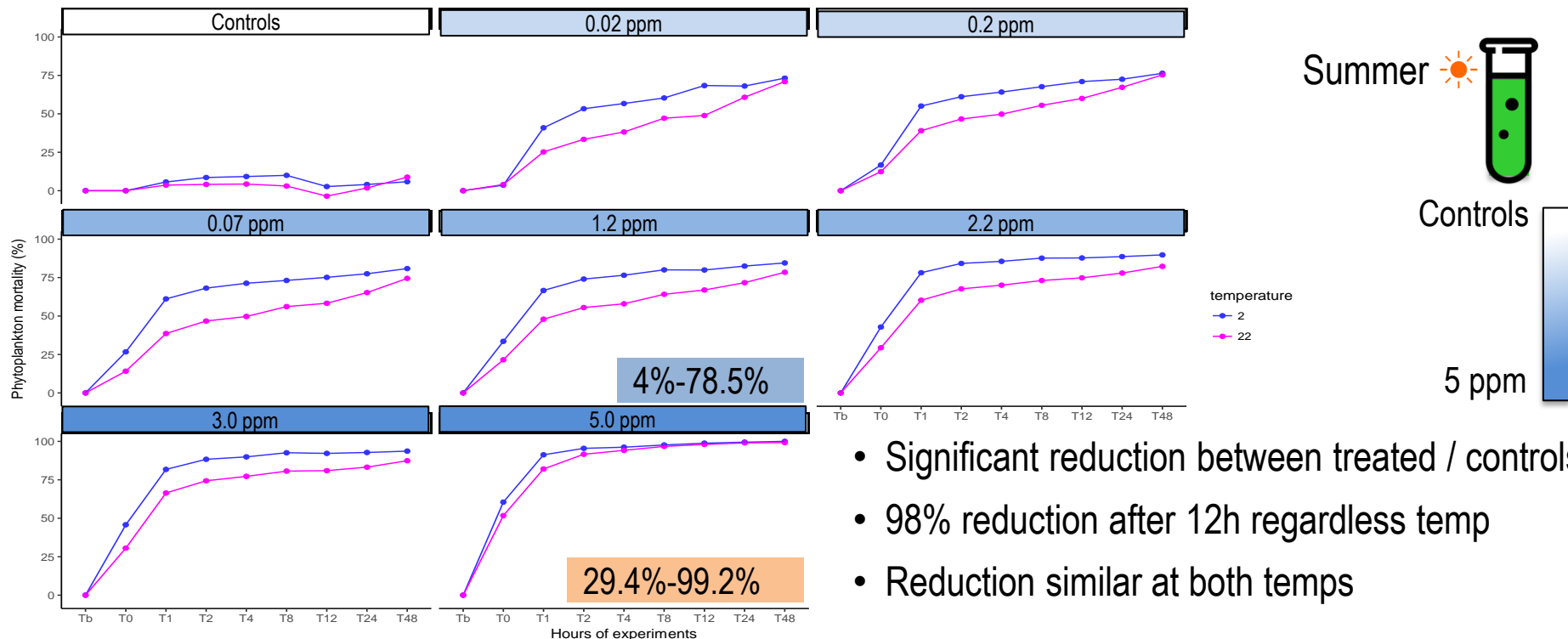
Results – Phytoplankton abundance



- Significant reduction between treated / controls
- 98% reduction after 12h regardless of temp



Results – Phytoplankton abundance



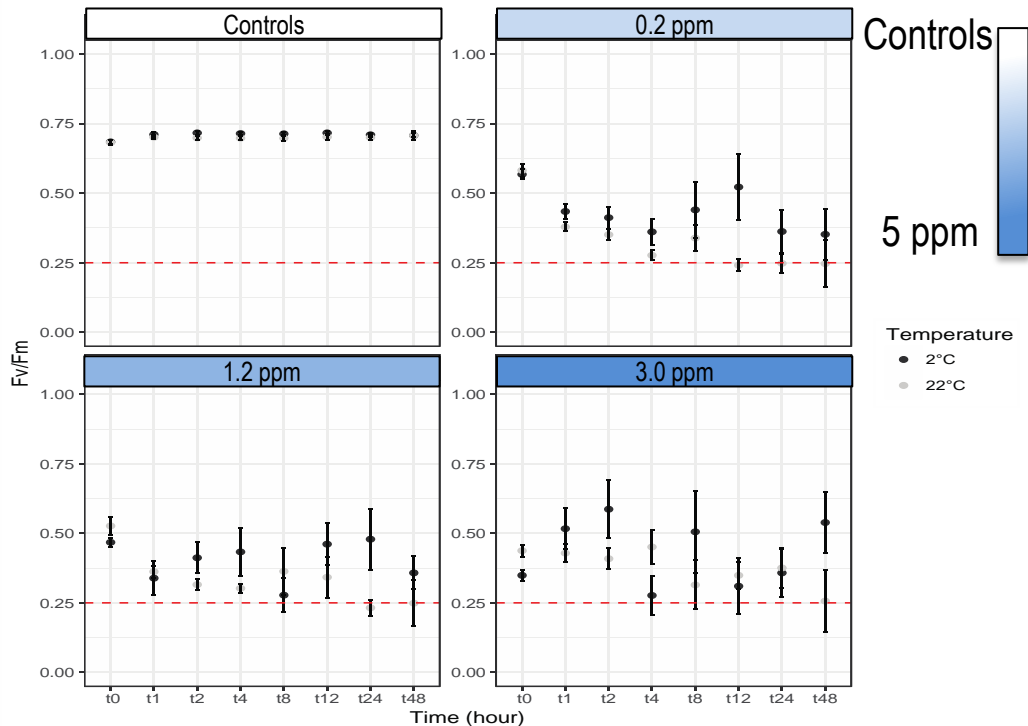
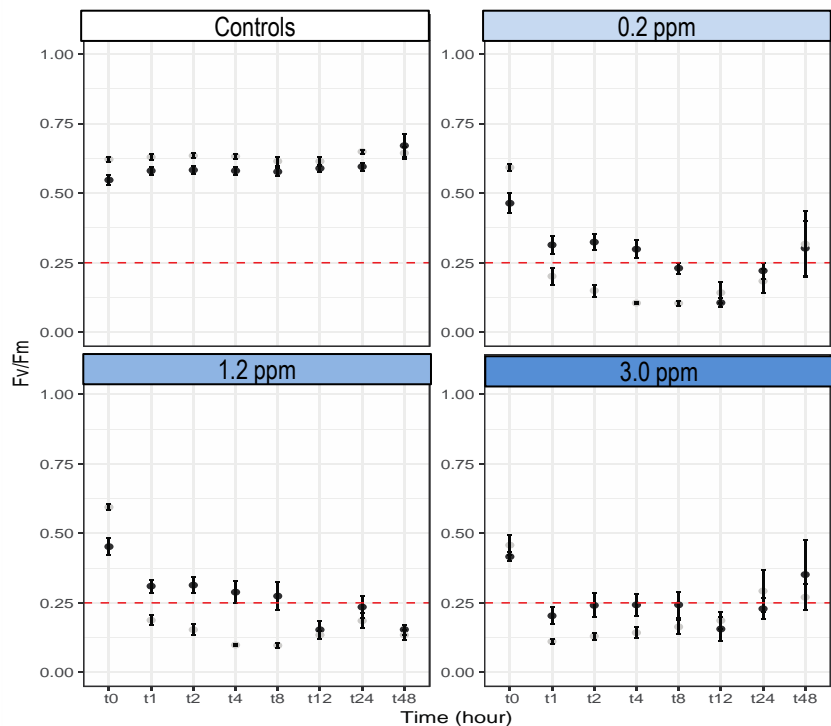
- Significant reduction between treated / controls
- 98% reduction after 12h regardless temp
- Reduction similar at both temps



Results – Photosynthetic efficiency

Winter ❄️

Summer ☀️





Summary

- Chlorine BW treatment may significantly reduce phytoplankton abundance
- Phytoplankton survival higher in winter, but decreases with high [chlorine]
- No significant differences between temperatures on [chlorine], but decay rate at low temperatures was less drastic
- Survival in winter was high, but photosynthetic efficiency still low (values ≤ 0.25). Survival lower in summer but photosynthetic efficiency still high
- Exposure time plays a role: longer contact with chlorine leads to greater reduction, regardless of temperature
- Chlorine may eliminate freshwater phytoplankton in ballast water at any temperature; more tests at large scales are needed to confirm these findings



Thanks to lab members and collaborators!

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Ballast Water Management

Convention entry into force September 8th, 2017

Taxonomical group	Organisms size class	IMO-D2 Standard
Zooplankton	$\geq 50 \mu\text{m}$	< 10 viable org./m ³
Phytoplankton	$\geq 10 - < 50 \mu\text{m}$	< 10 viable cell per mL
Bacteria	<i>E. coli</i>	< 250 cfu/100mL
	Intestinal Enterococci	< 100 cfu/100mL
	<i>Vibrio cholerae</i>	< 1 cfu/100mL

