Effects of Climate Change on the Physiology of HAB species in DIB and its Consequences on Trophic Transfer

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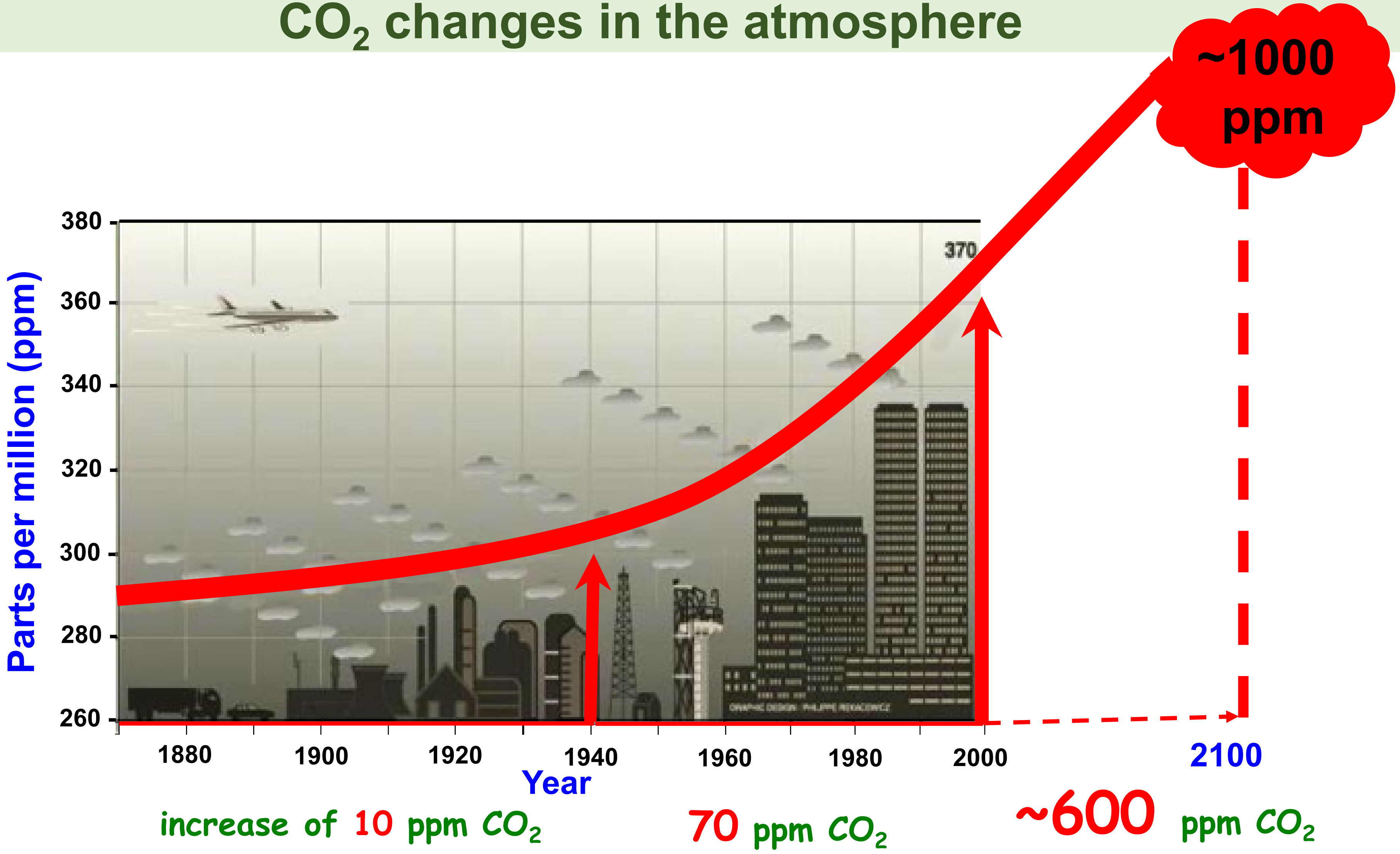
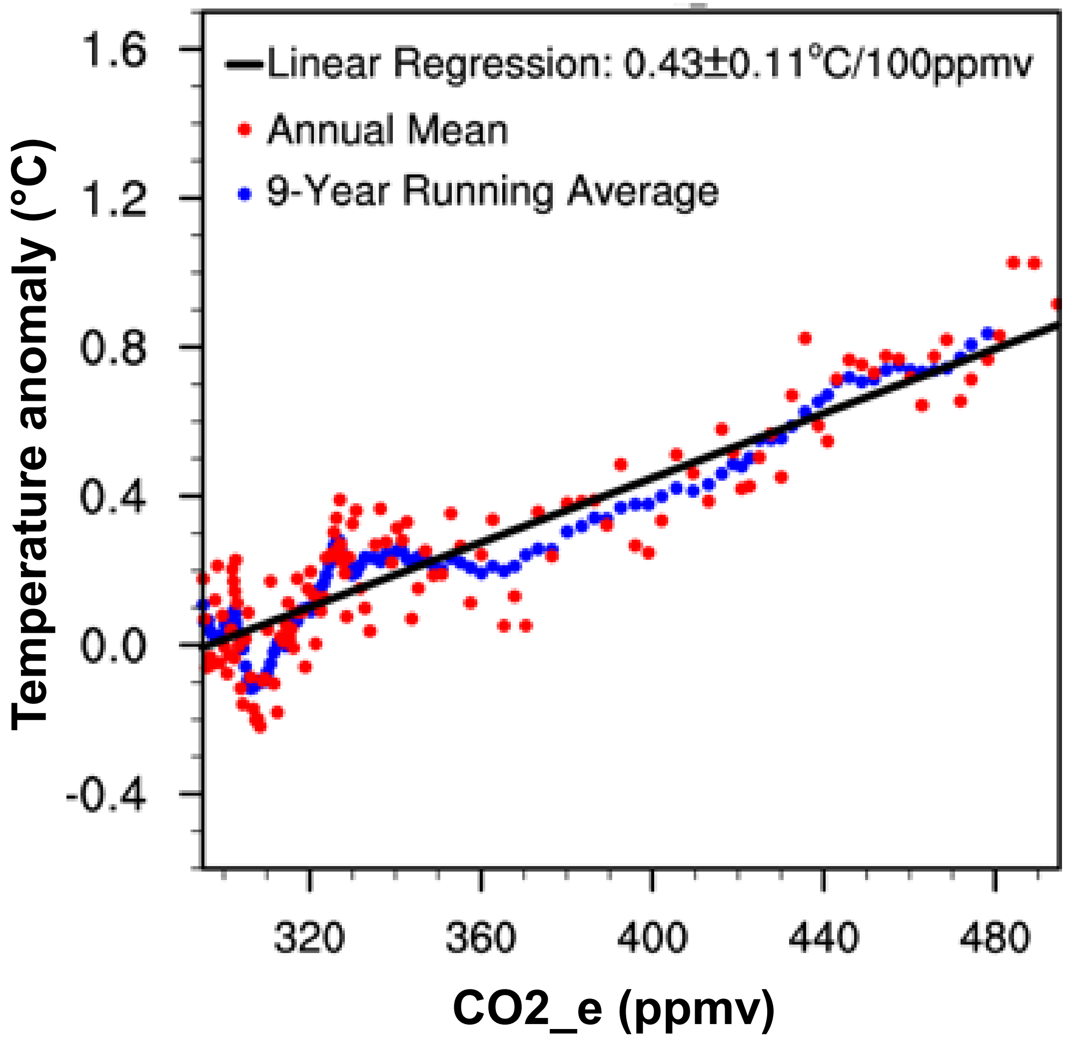
Climate Changes

CO_2 changes in the atmosphere

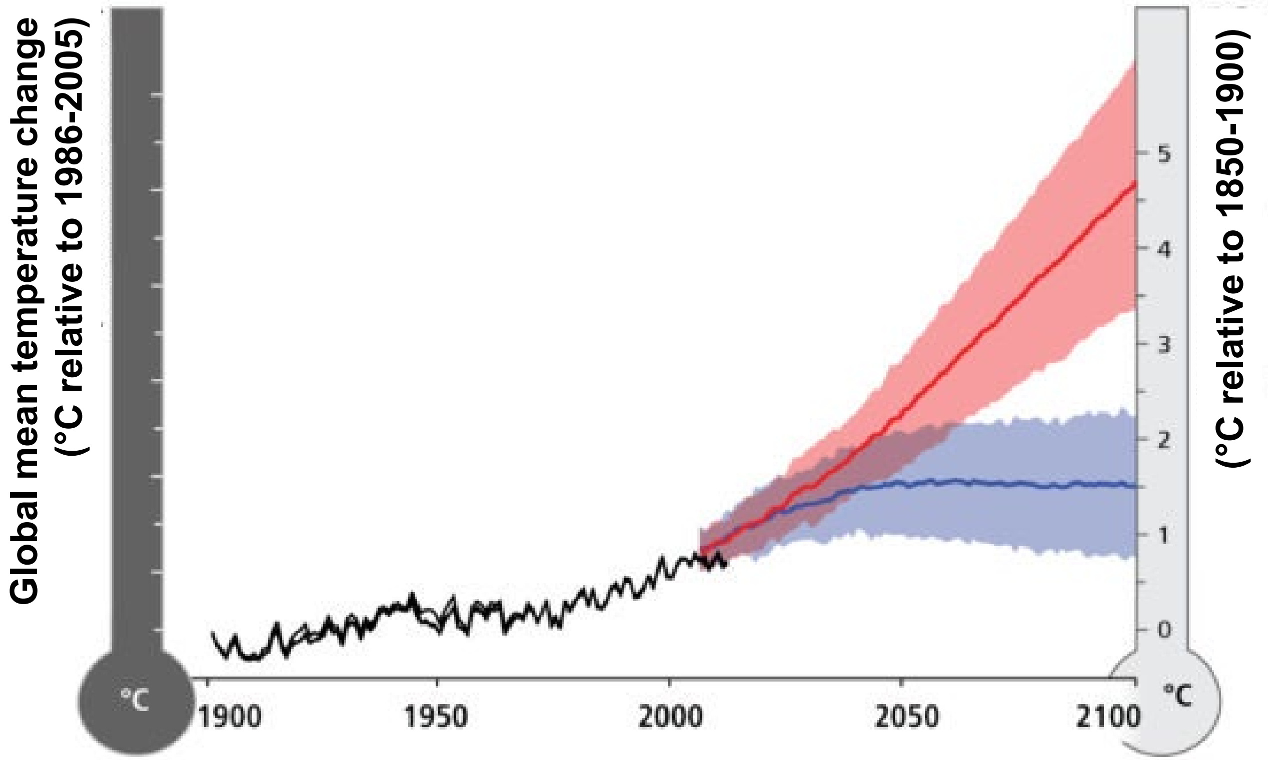


Climate Changes

Global warming of ~1.5-4.5 °C



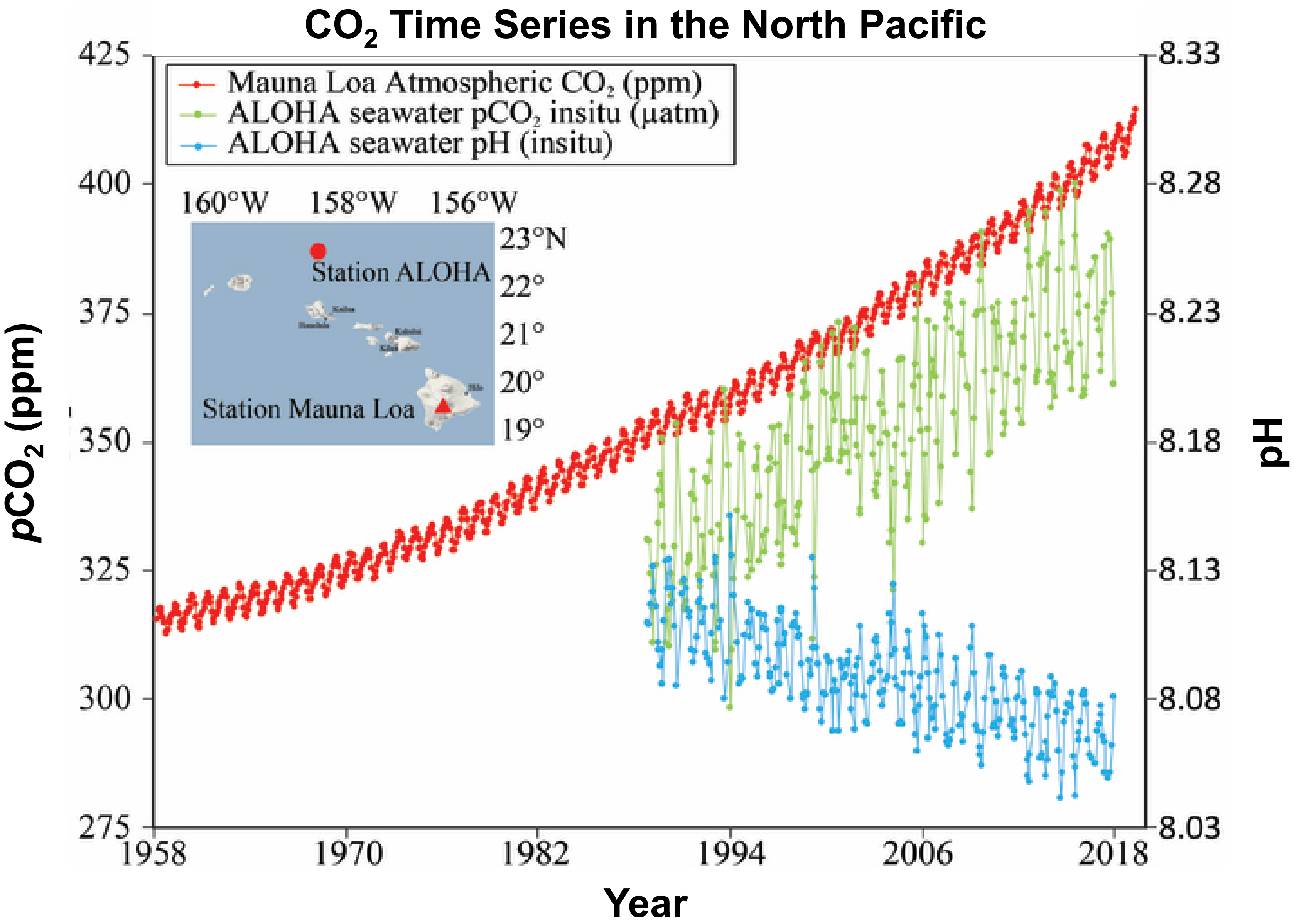
Wu et al. (2019), *Nature Climate and Atmospheric Science*



IPCC, 2014

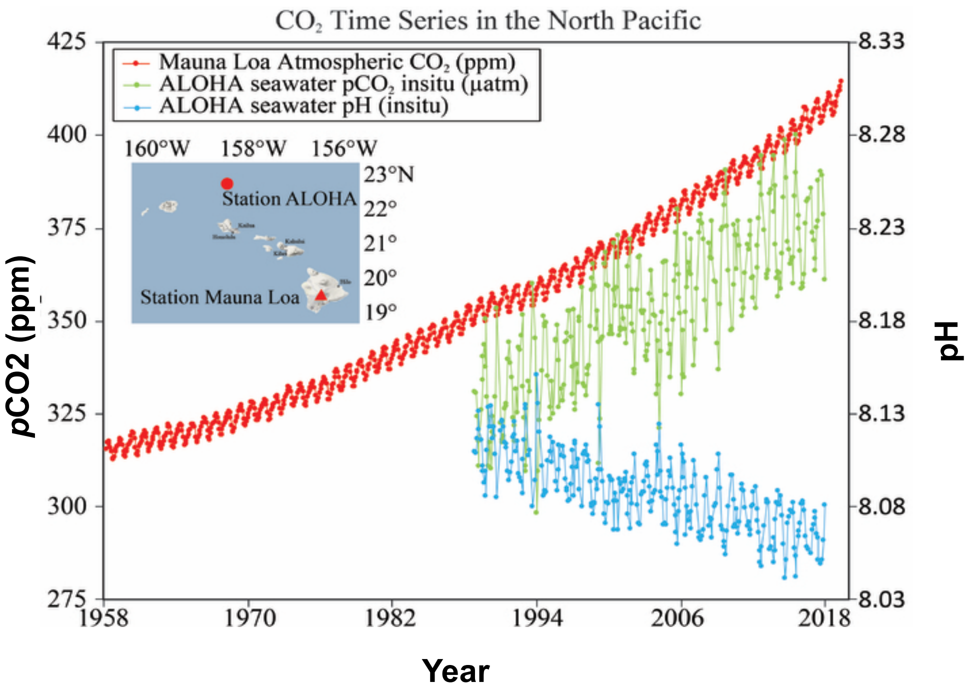
Climate Changes

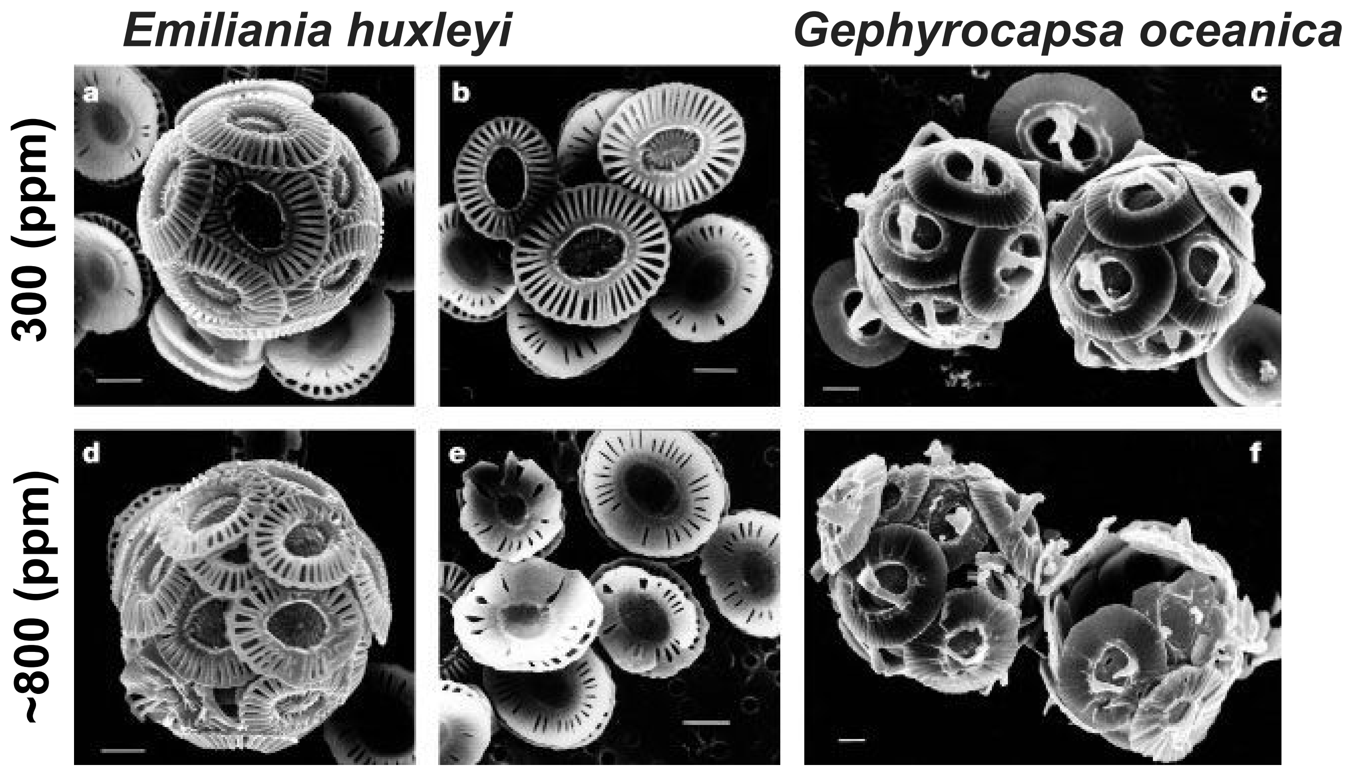
Ocean acidification (= pH drop of 0.3-0.4)



Climate Changes

Ocean acidification (= pH drop of 0.3-0.4)

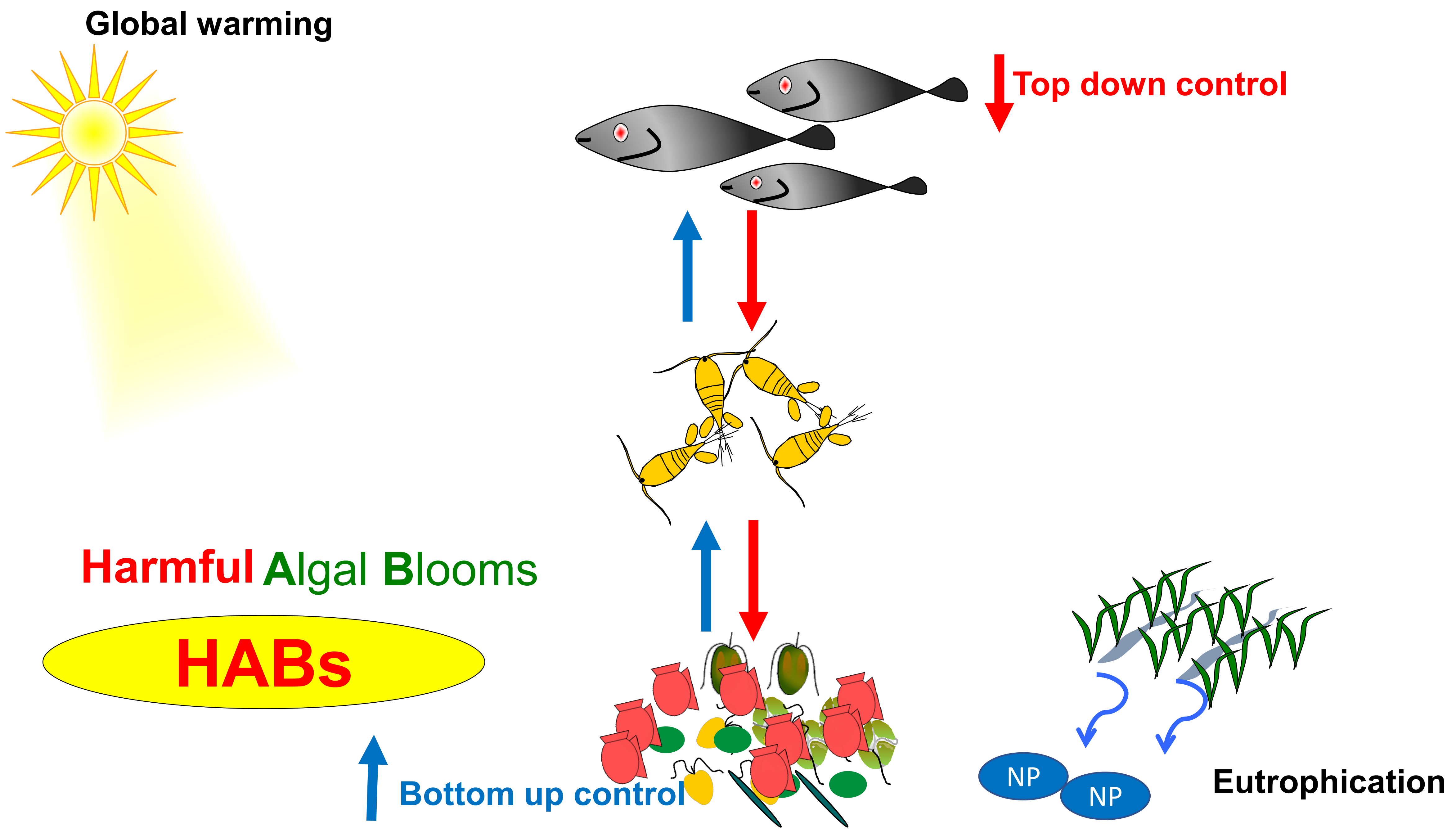




Reibesell et al., 2000

Dissolution of pteropod's shell

NOAA-PMEL Carbon program

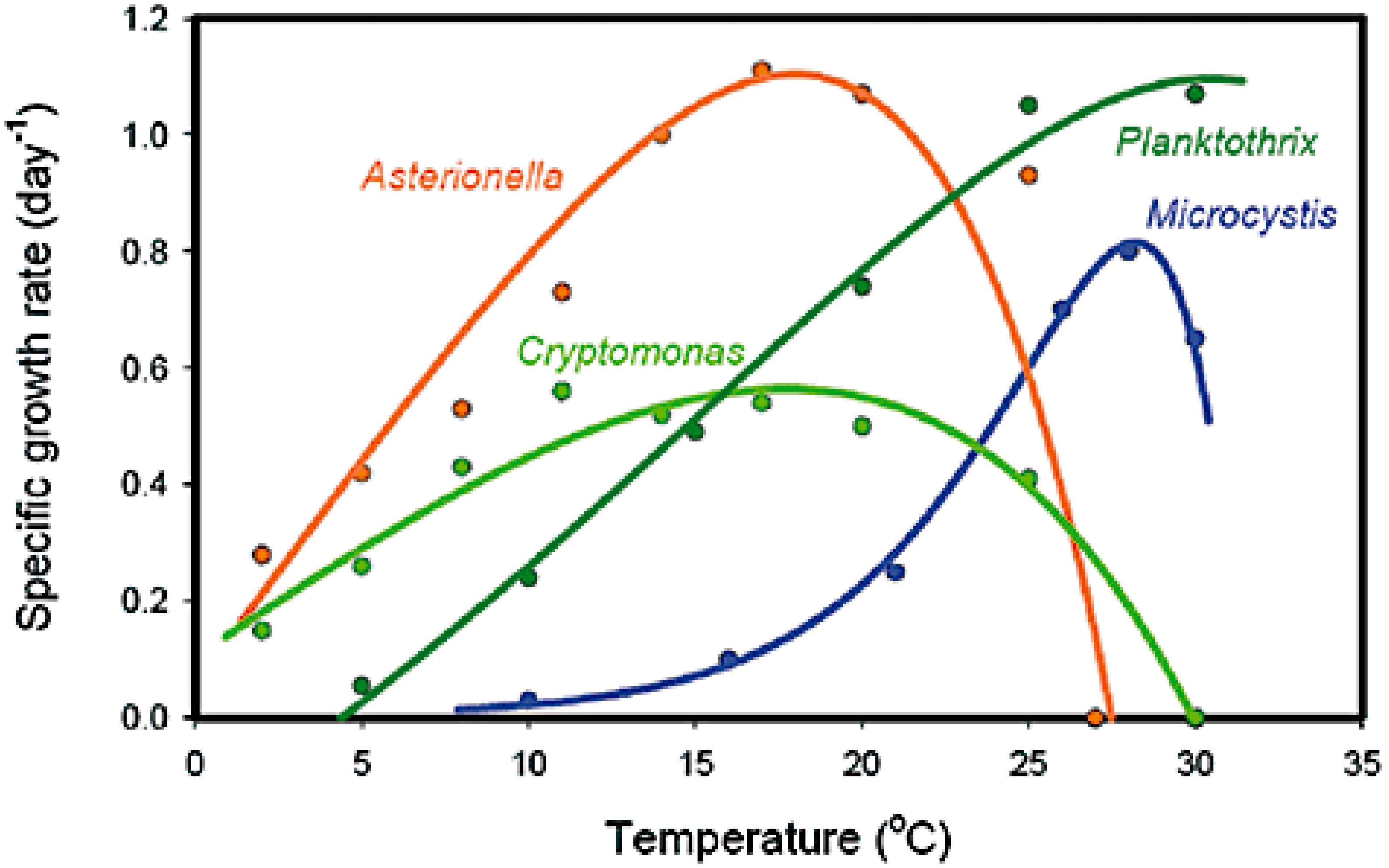


Global warming
Top down control
Harmful Algal Blooms
HABs
Bottom up control
NP
NP
Eutrophication

Global warming effects on HABs

Favors the growth of warm water HAB species

Rising temperature favors CyanoHABs

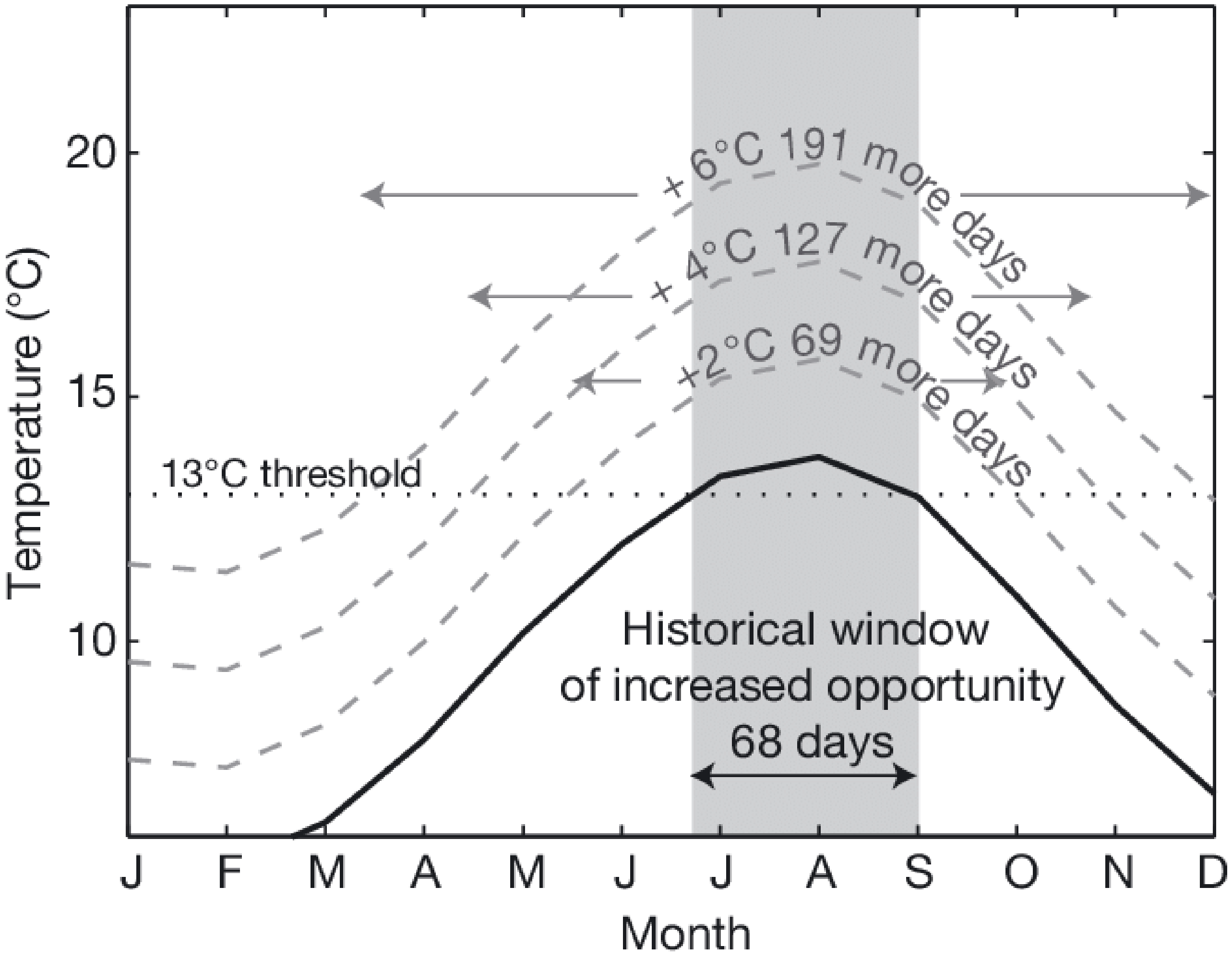


Paerl and Jef Huisman (2009)

Global warming effects on HABs

Increases the temporal window for bloom formation

Expansion of the temporal window for *Alexandrium catenella* bloom formation



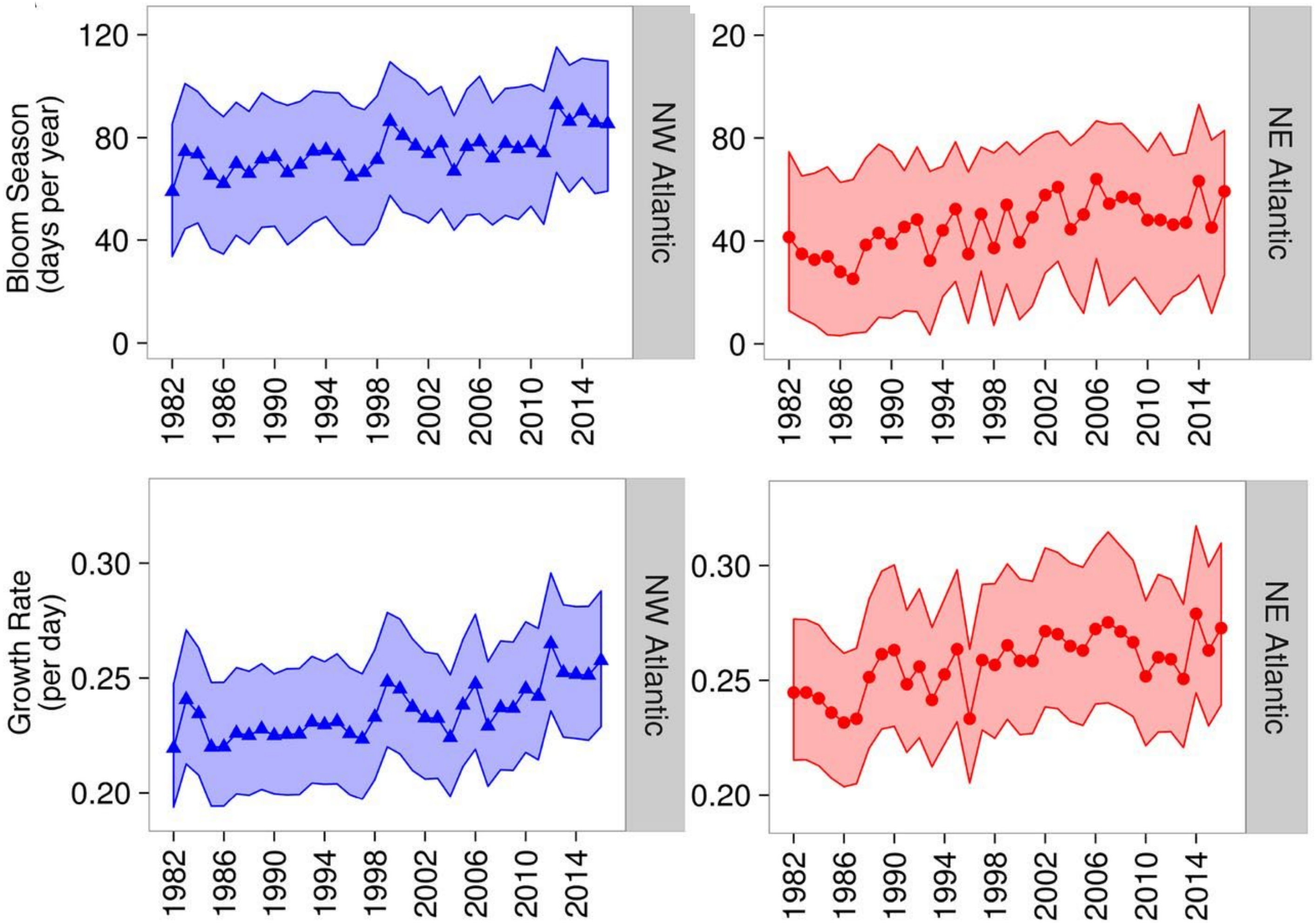
Moore et al (2008)

Ocean warming effects on HABs

Increase of temporal window for bloom formation

Ocean warming has expanded the niche of toxic algal blooms in the North Atlantic and North Pacific oceans

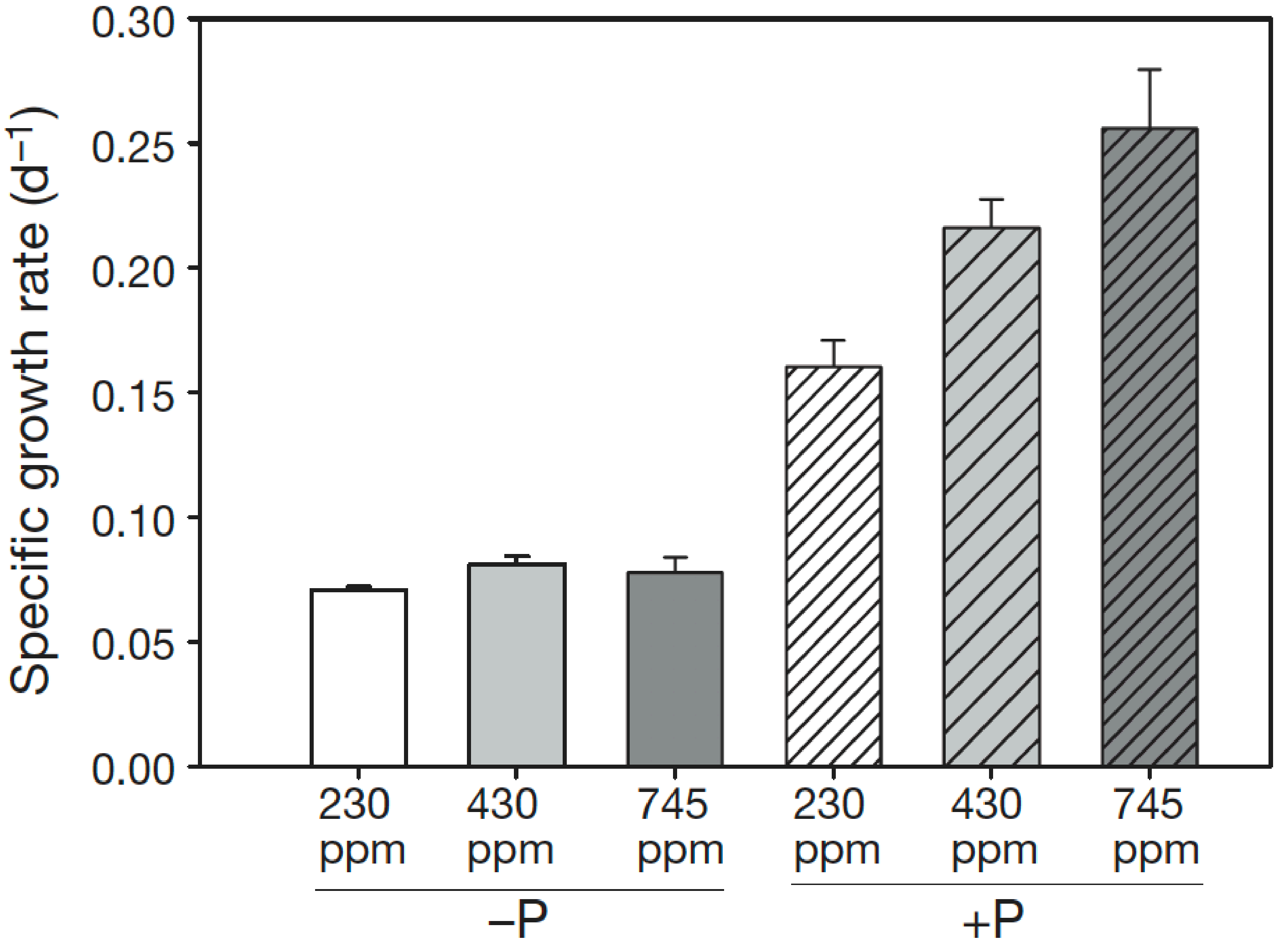
Dinophysis acuminata



Gobler et al (2017), *PNAS.*

Ocean acidification effects on HABs

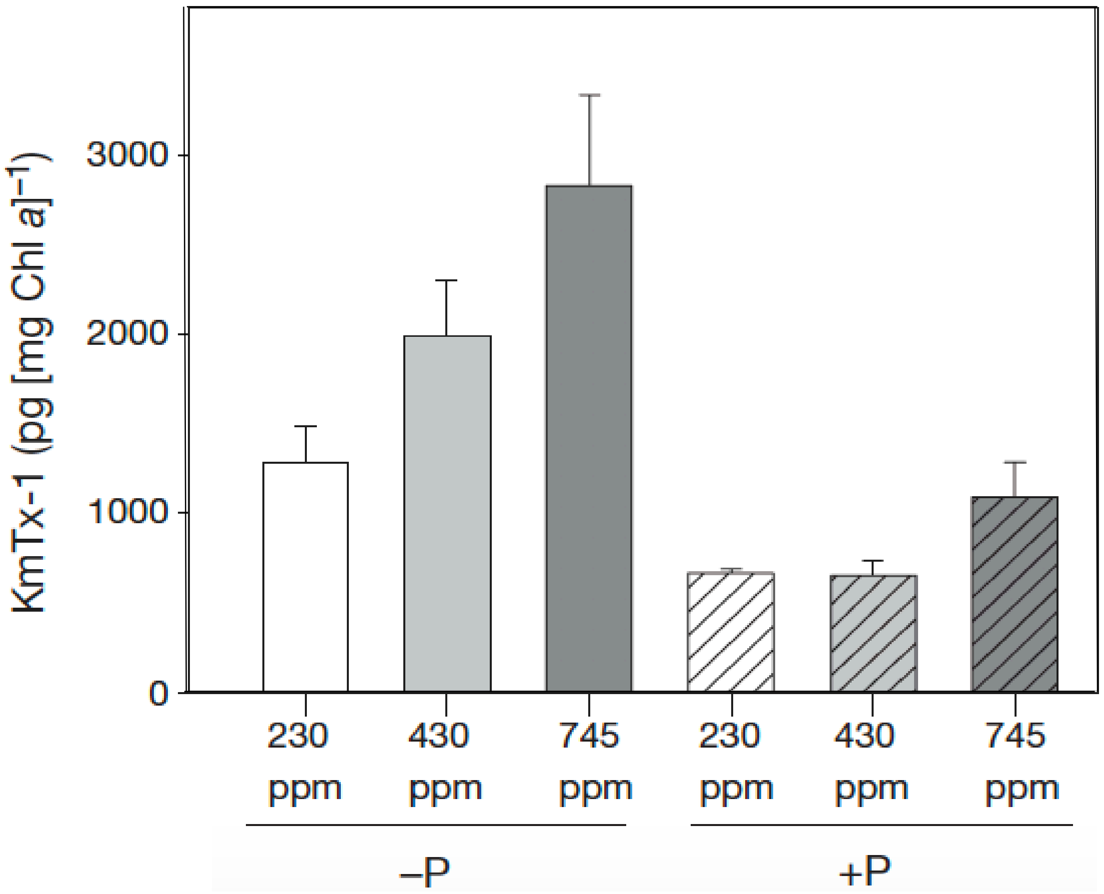
Increases the growth of some HAB species

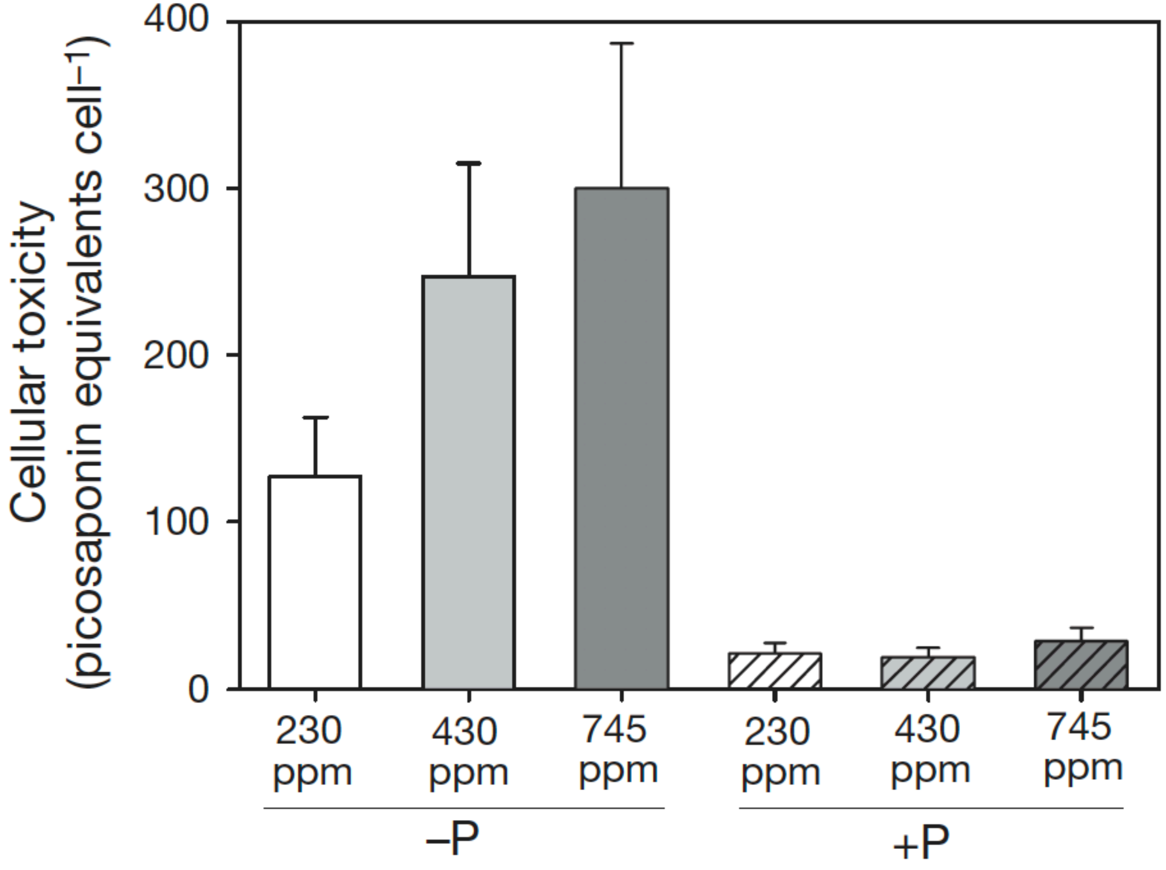


Fu et al (2010), Aquat Microb Ecol

Ocean acidification effects on HABs

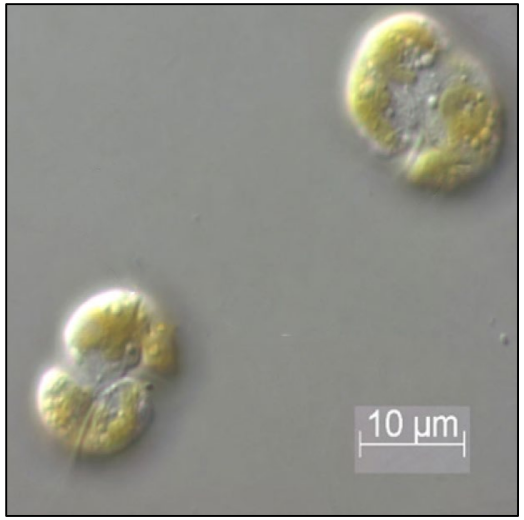
Increases the cell toxicity of some HAB species

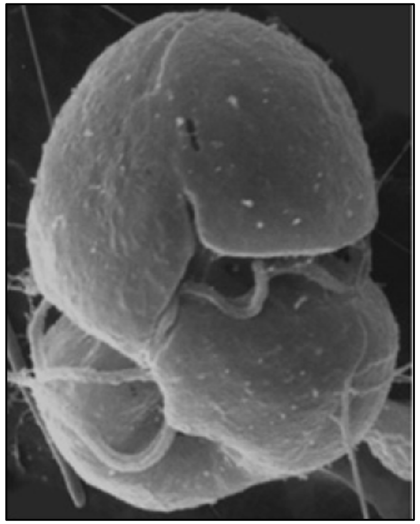




Fu et al (2010), Aquat Microb Ecol

Karlodenium veneficum





- A planktonic, photosynthetic dinoflagellate with a global distribution
- Produces Karlotoxins (KmTx) with lytic, ichthyotoxic, and allelopathic properties.

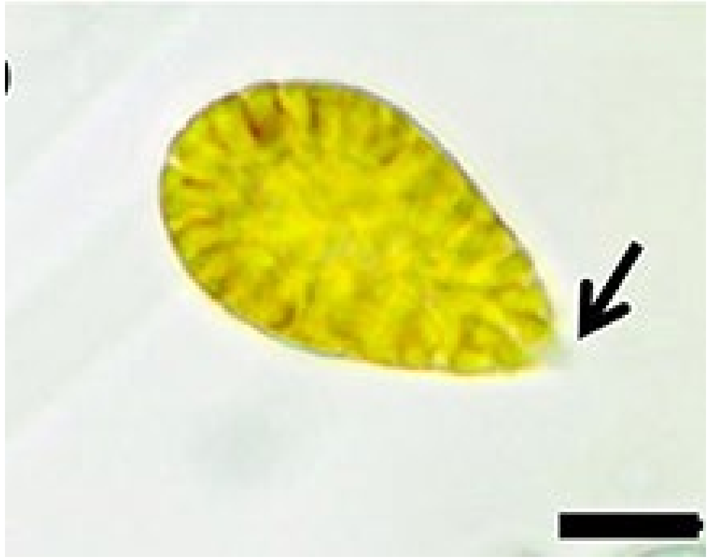
Place et al., Harmful algae (2012)

Raphidophytes:

- Form blooms associated with massive fish kills
- Produce ROS and neurotoxin-like compounds

Heterosigma akashiwo

Engesmo et al. (2016), Phycologia



Chattonella subsalsa

Viana et al. (2019), FMRS

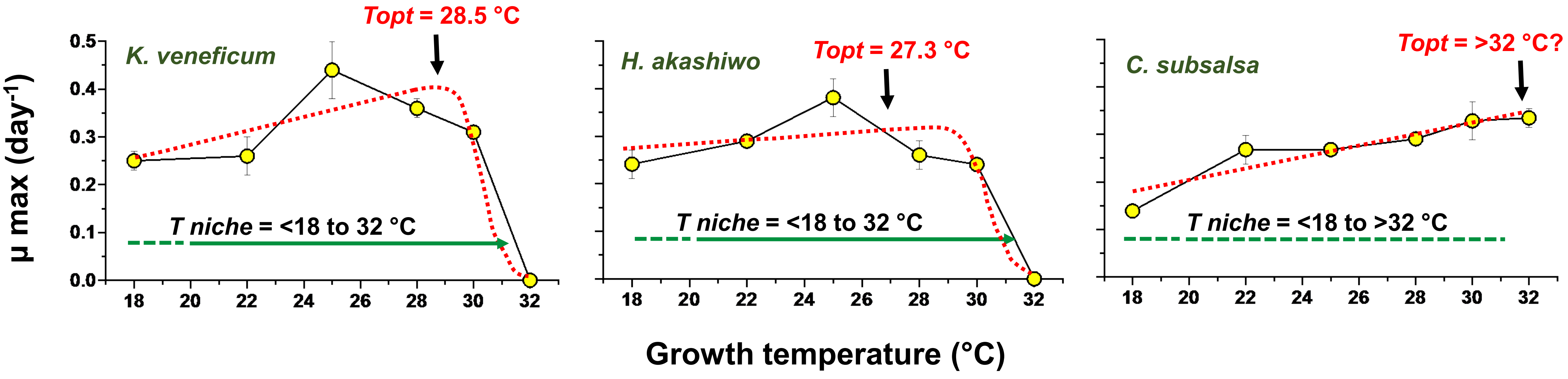
Primary Questions

Temperature effect on HAB species in DIB

- Are the Thermal niche and Topt of 3 species similar?
- How does cell toxicity changes with temperature and growth?

Temperature effect on the growth of HAB species

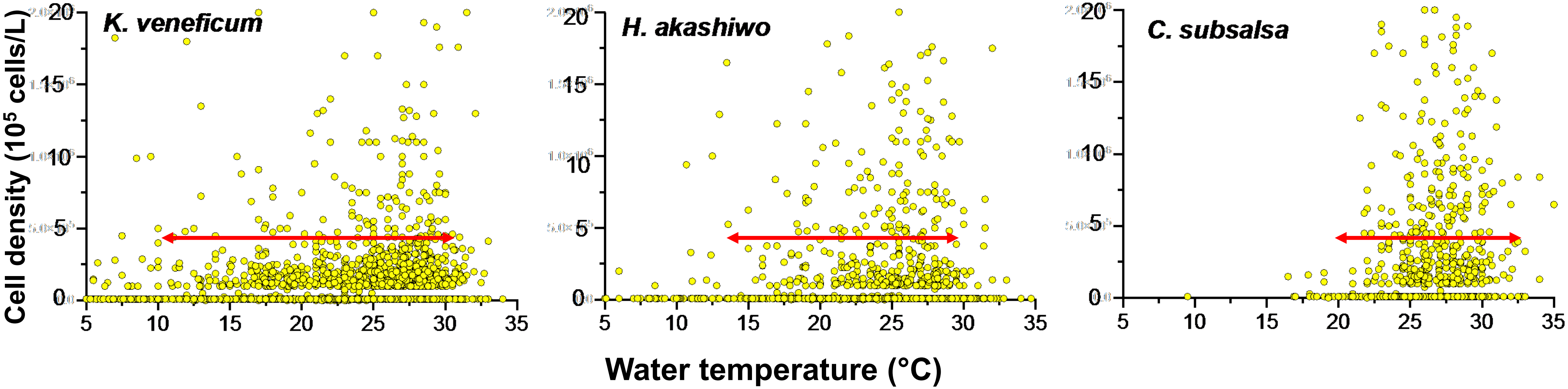
TPCs of *K. veneficum*, *H. akashiwo* and *C. subsalsa*



- 3 HAB species showed different *Topt*
- *C. subsalsa* is the most resilient for warming

HAB species abundance in DIB

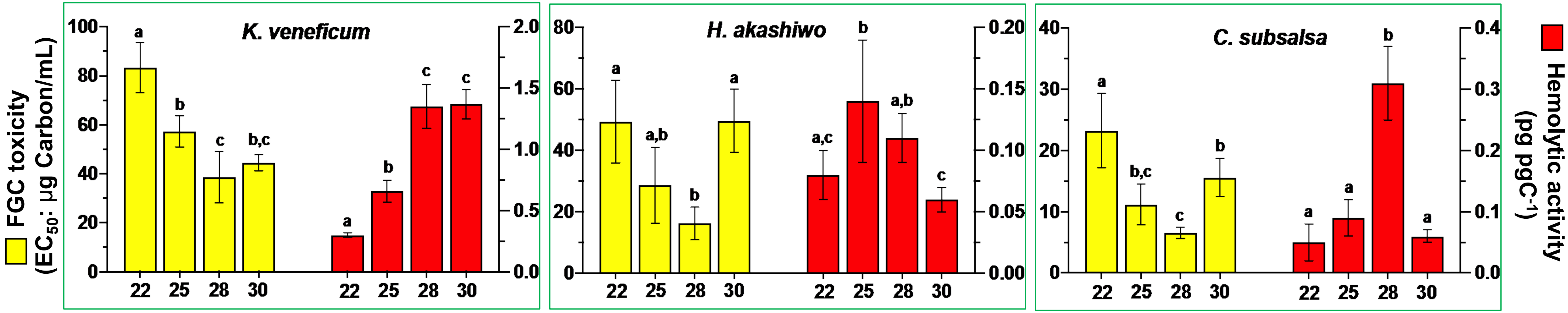
K. veneficum, *H. akashiwo* and *C. subsalsa* abundance 2002-2018



UD Citizen Monitoring Program (https://www.citizen-monitoring.udel.edu/)

Temperature effect on HAB toxicity

Hemolytic activity and FGC mortality of *K. veneficum*, *H. akashiwo* and *C. subsalsa*



- *K. veneficum* toxicity was higher at >28 ºC while raphidophyte toxicity was higher at 25-28 ºC.

- *K. veneficum* had greater hemolytic activity and raphidophyes had higher FGC mortality

What about high Temperature AND high CO_2?

Primary Questions

High T and CO_2 effect on *K. veneficum*-DIB

- Could climate change potentially increase the magnitude of *K. veneficum* blooms?

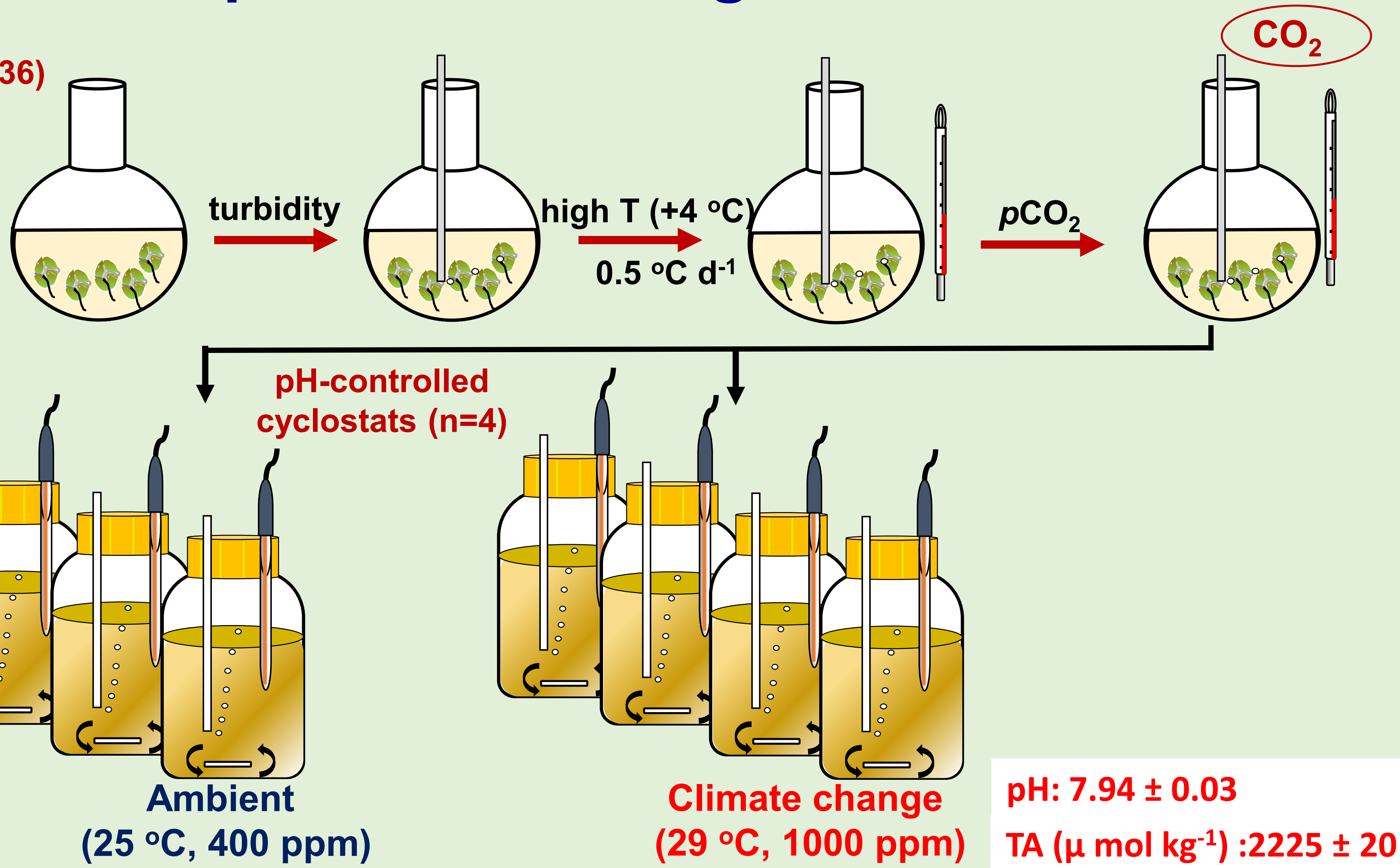
- How does climate change influence the physiology of *K. veneficum* and the copepod (*A. tonsa*)?

- What are the consequences of shifts in algal physiology on trophic transfer?

Experimental design

K. veneficum –DIB (CCMP 2936)

f/2 - 20 psu
12:12 L:D cycle
~100 μmol photons m^{-2} s^{-1}

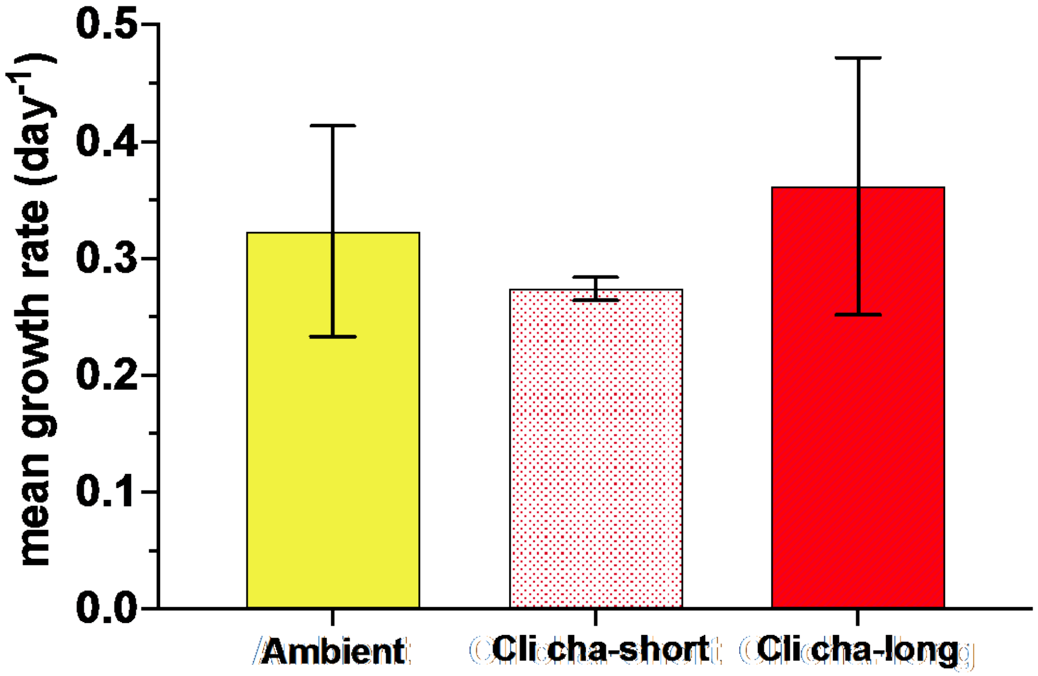


pH: 8.23 ± 0.03
TA (μ mol kg^{-1}) :2225 ± 20
DIC(μ mol kg^{-1}): 2176 ± 91
pCO_2 (ppm): 440 ± 29

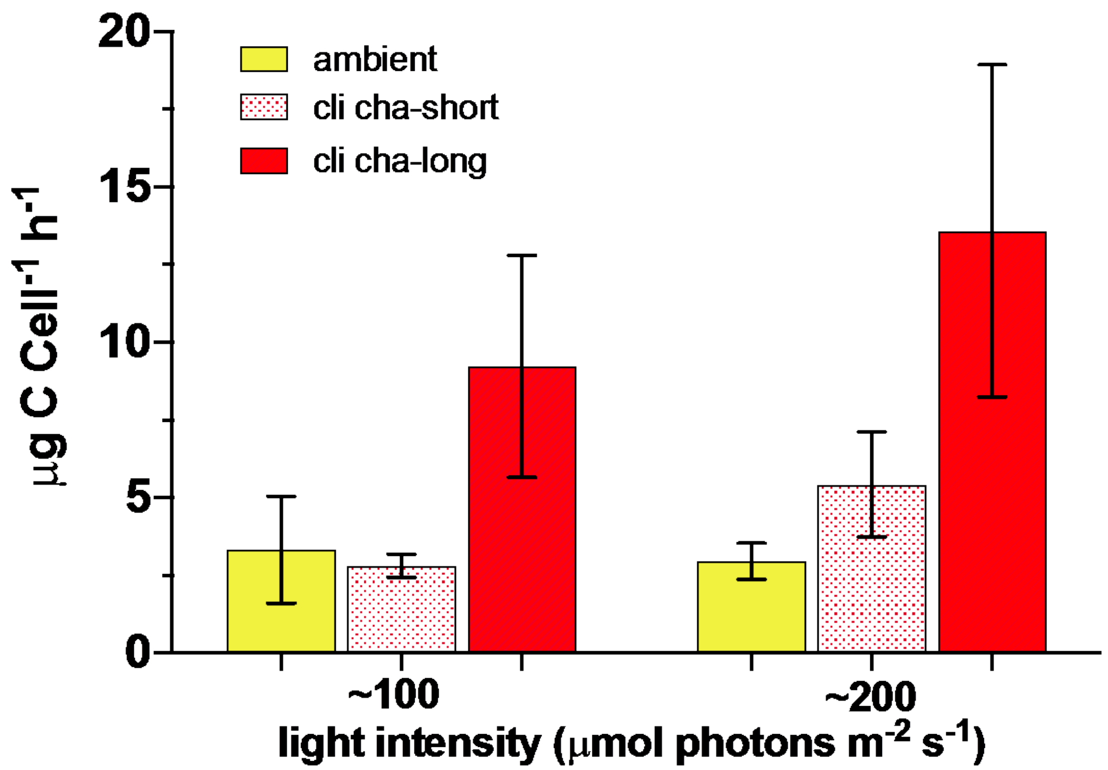
pH: 7.94 ± 0.03
TA (μ mol kg^{-1}) :2225 ± 20
DIC(μ mol kg^{-1}): 2496 ±
pCO_2 (ppm): 1072 ± 113

Growth rates and Primary productivity

Hemolytic activity and FGC mortality of *K. veneficum*, *H. akashiwo* and *C. subsalsa*



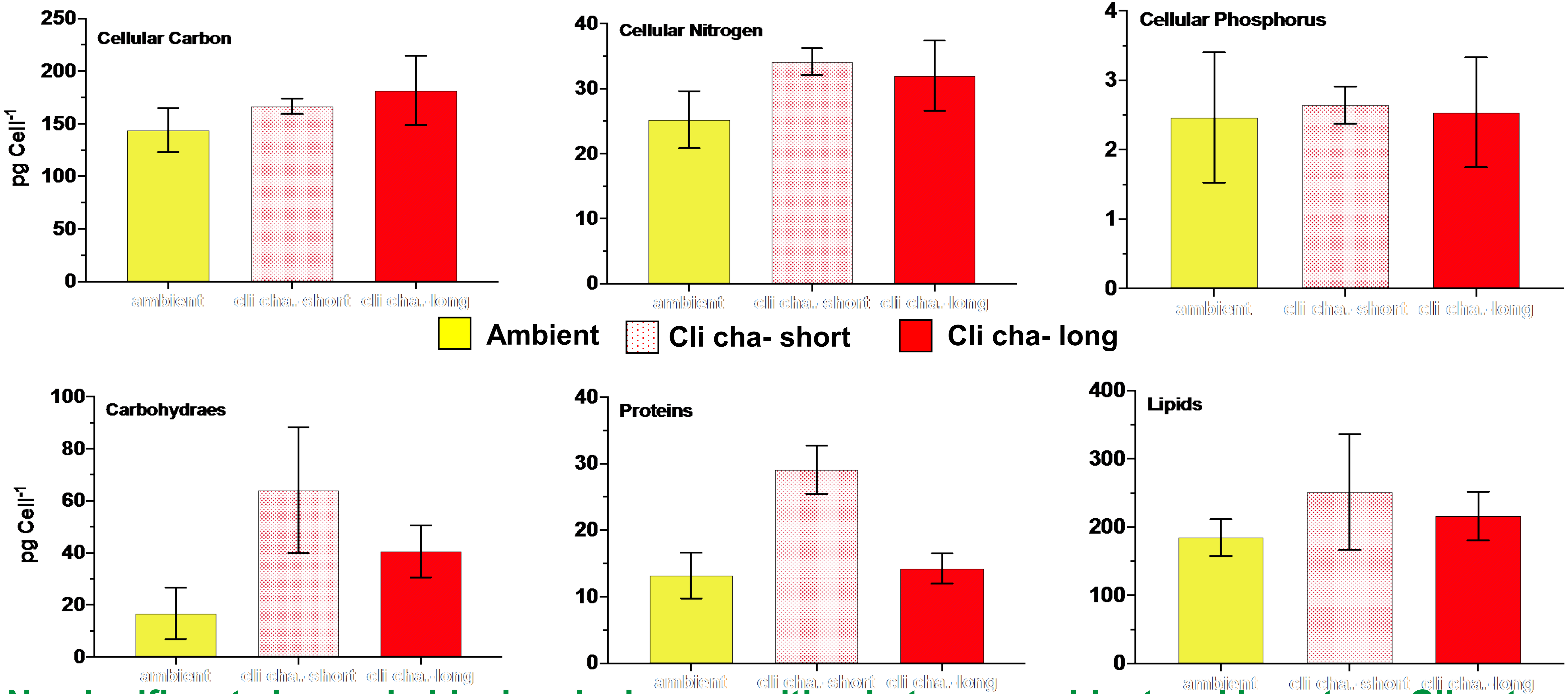
Cell growth rates slightly increased under Climate change conditions



Primary productivity increased under Climate change conditions

Biochemical composition of *K. veneficum*

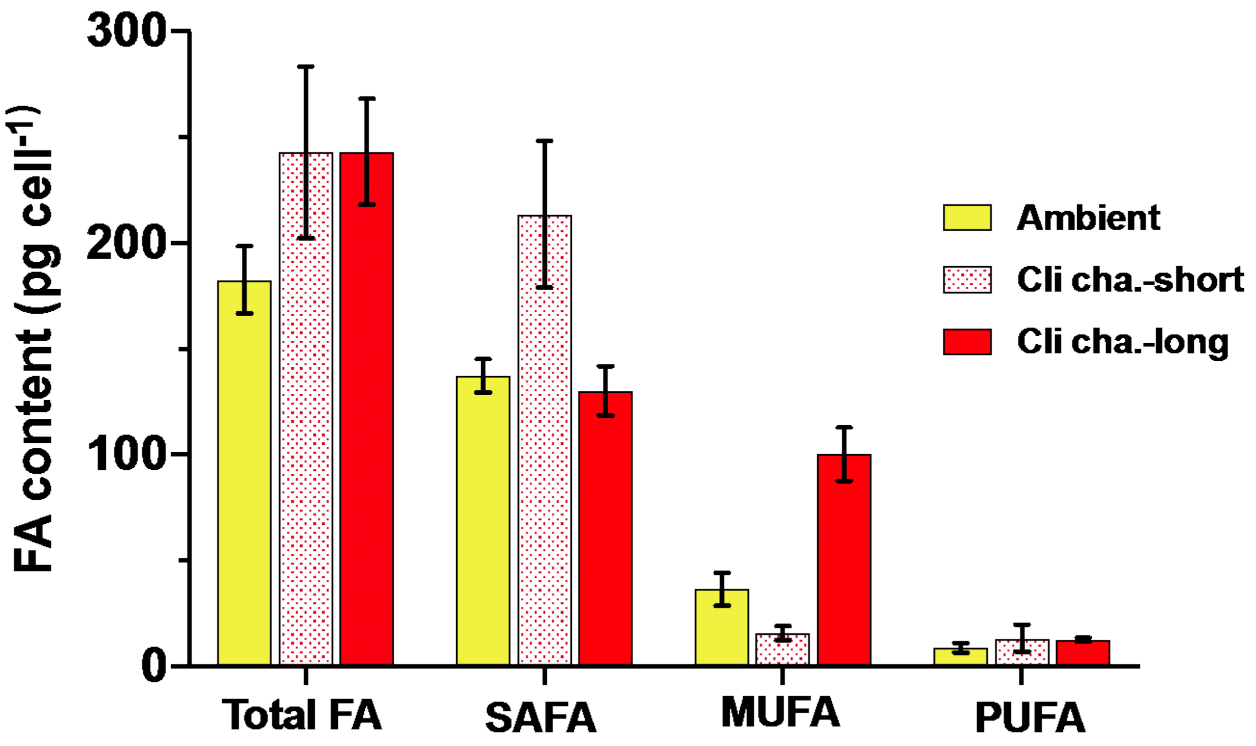
Cell quotas of C,N,P and Carbohydrates, proteins and lipids

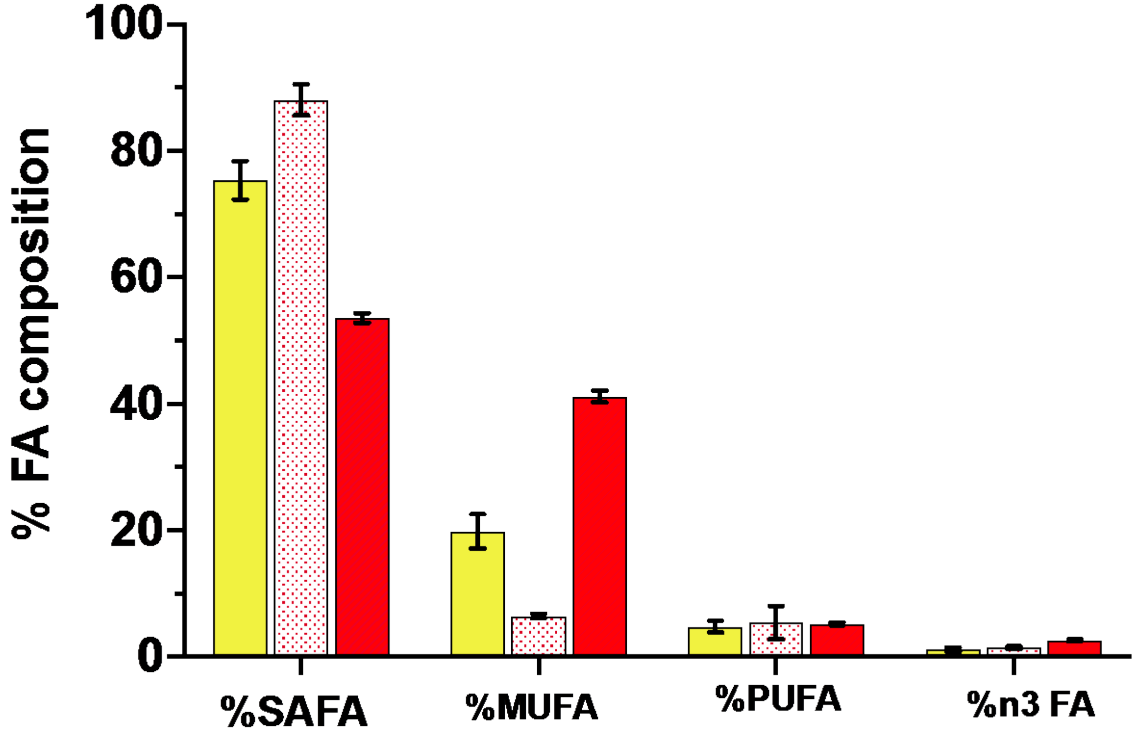


No significant change in biochemical composition between ambient and long term Climate change conditions

Cellular fatty acid composition

Total and % FA contents and composition

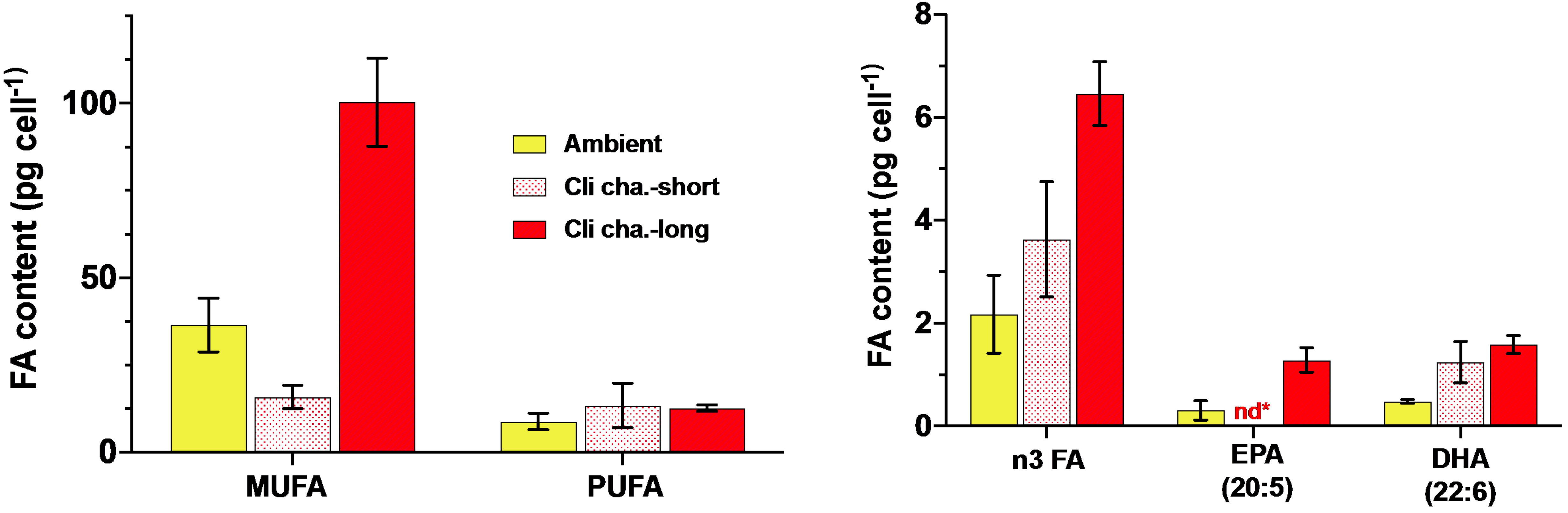




Long term Climate change conditions decreased the %SAFA and increased the %MUFA.

Cellular fatty acid composition

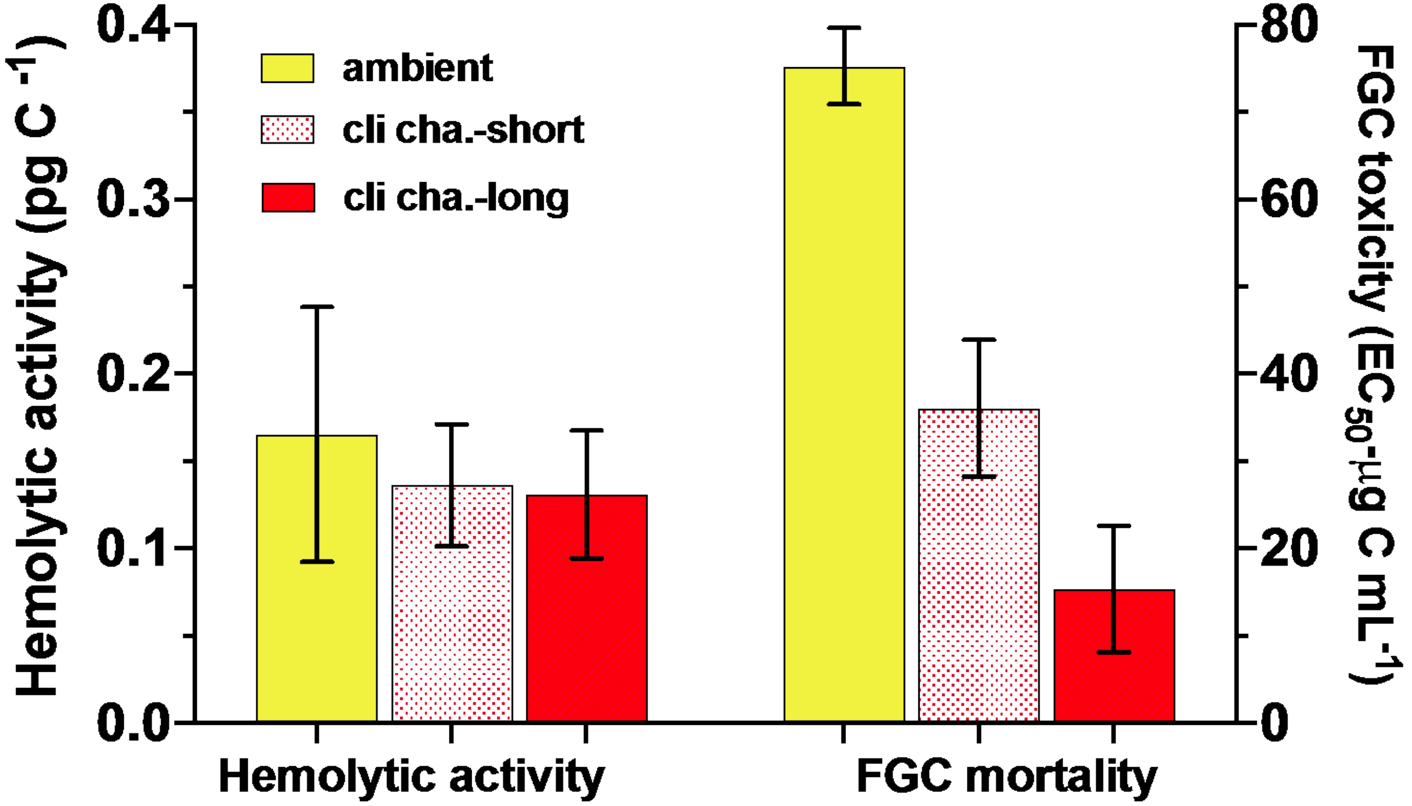
% MUFA, PUFA and n3 FA contents



Long term Climate change conditions increased the % n3 FA including EPA and DHA.

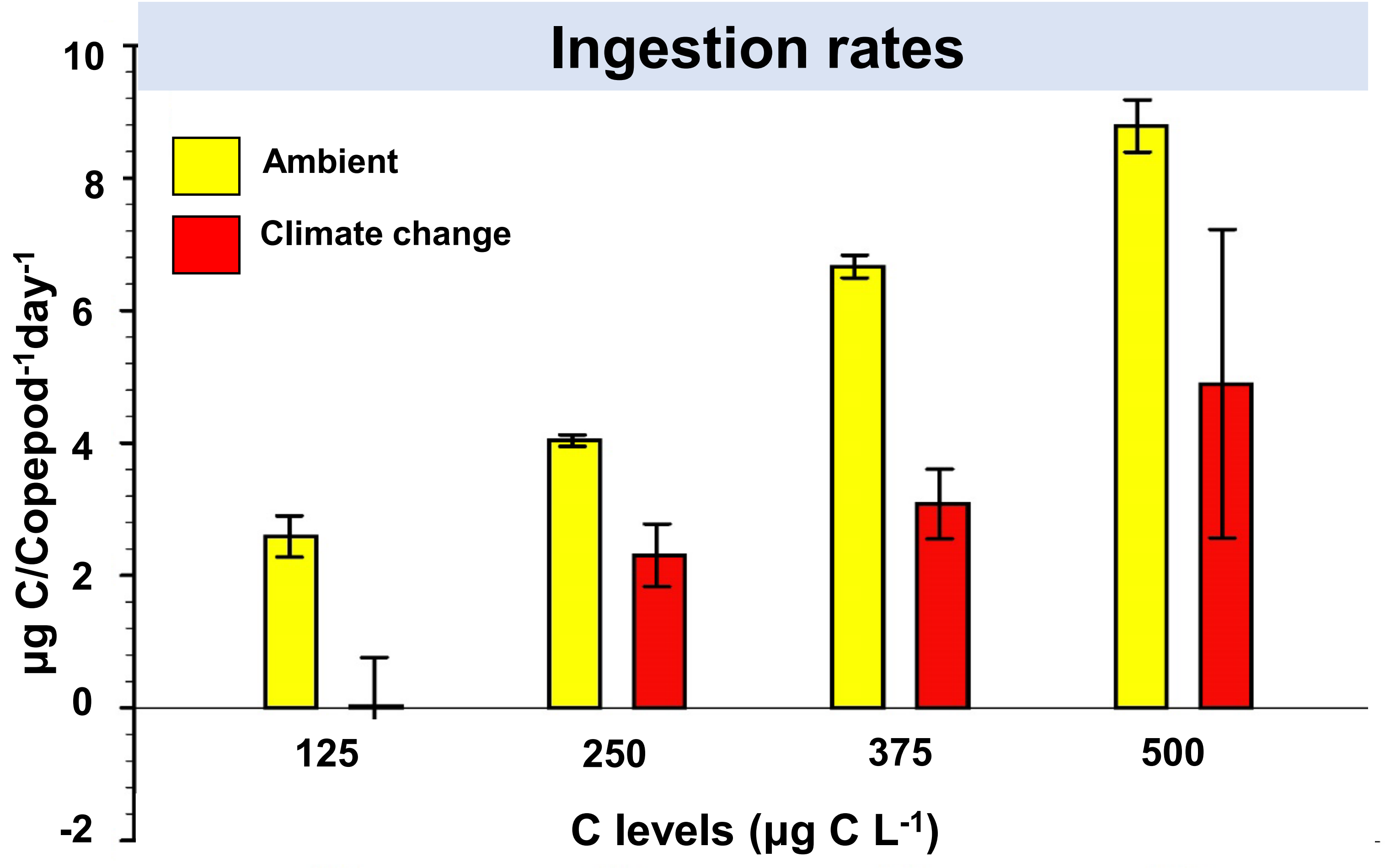
Cell toxicity

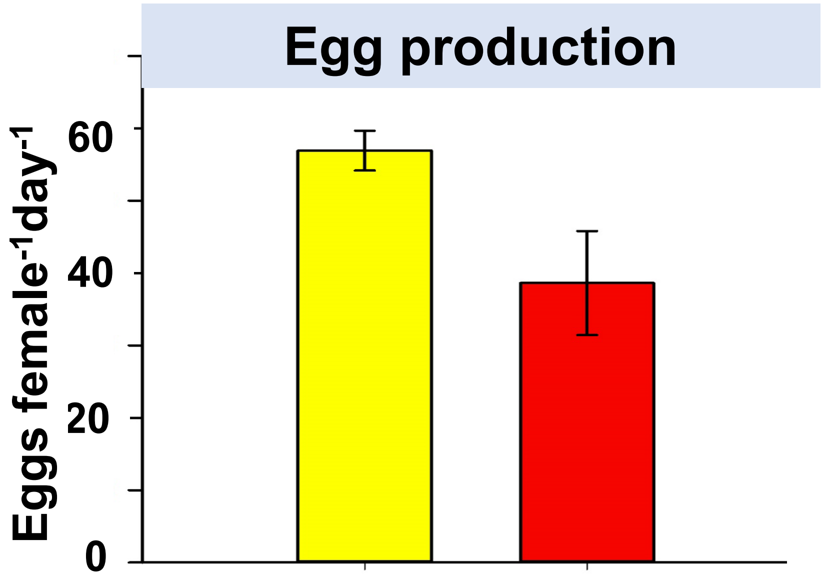
Hemolytic activity and FGC mortality

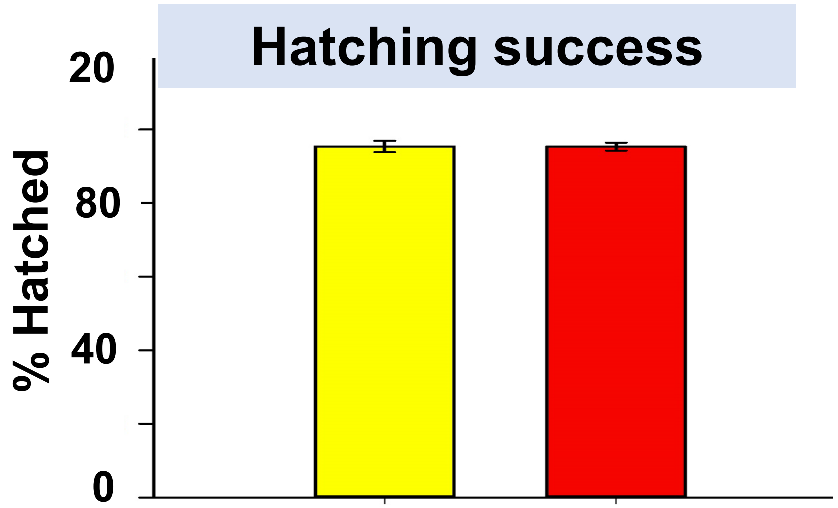


- No significant difference of hemolytic activity
- *K. veneficum* at climate change conditions resulted in significantly higher fish gill cell mortalities.

Grazing with Acclimated Copepods





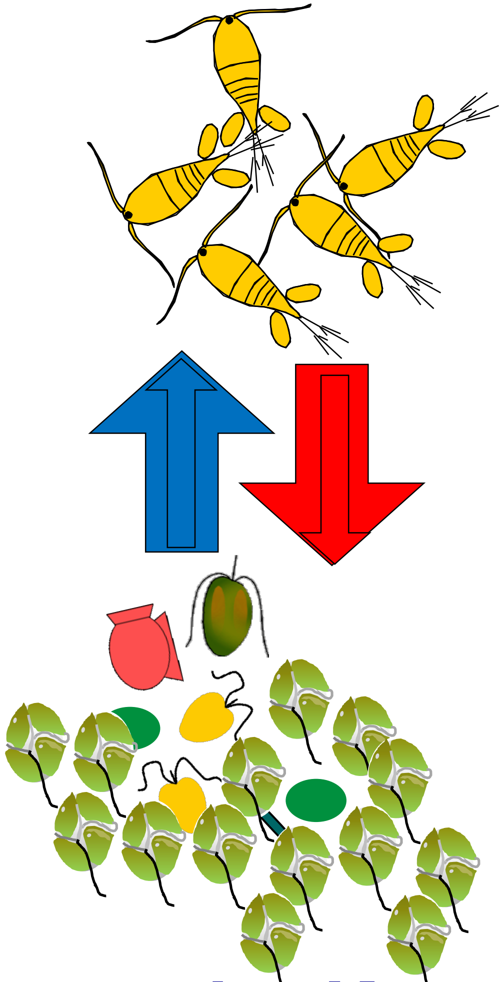


- Grazing rates decreased at climate change conditions
- Egg production reduced, Hatching success unaffected
- Total fecundity reduced

in a climate change scenario (~2100)

Increase of:

- Growth rates
- Primary productivity
- Cell quotas of Carbohydrates, and Lipids
- Cell toxicity
- %MUFA and n3 FA



Decrease of:

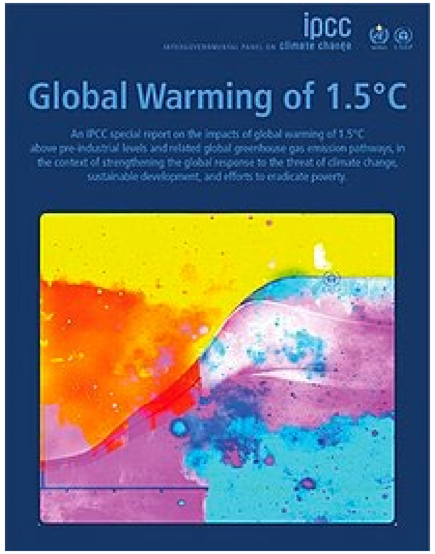
- Palatability?
- Grazing pressure
- Copepod fecundity

Climate changes may enhance the *K. veneficum* bloom formation and reduce the trophic transfer efficiency.

Acknowledgements

- **NOAA National Center for Coastal Ocean Science for funding support**
- **Warner, Coyne and Cohen lab members**
- **Edward Whereat and UD Citizen monitoring program (https://www.citizen-monitoring.udel.edu/)**

NOAA NCCOS NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE



Key Messages:

- To avoid total climate disaster the global community must limit global warming to 1.5 °C.
- a 45% decrease in global net anthropogenic CO_2 emissions from 2010 level by 2030 is needed.
- This requires rapid transitions in energy, land, urban, transportation, buildings, infrastructure, and industrial systems.
- Local and Indigenous knowledge is important for limiting global warming.
- Capacity-building and international cooperation are urgently needed to limit global warming.

2 ºC warming =~99% decline
1.5 ºC warming =~79-90% decline

https://www.bccic.ca/why-1-5oc-matters/

https://www.ipcc.ch/sr15/chapter/summary-for-policy-makers/

Experimental design