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

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Climate Changes

CO₂ changes in the atmosphere

- Increase of 10 ppm CO₂
- 70 ppm CO₂
- ~600 ppm CO₂
- ~1000 ppm CO₂
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)

CO₂ Time Series in the North Pacific

- Mauna Loa Atmospheric CO₂ (ppm)
- ALOHA seawater pCO₂ insitu (μatm)
- ALOHA seawater pH (insitu)

Station ALOHA
Station Mauna Loa

160°W  158°W  156°W
23°N
22°
21°
20°
19°

Year

pCO₂ (ppm)
345
350
355
360
365
370
375
380
385
390
400
425

pH
8.33
8.28
8.23
8.18
8.13
8.08
8.03
Climate Changes

Ocean acidification (= pH drop of 0.3-0.4)

**CO2 Time Series in the North Pacific**

- Mauna Loa Atmospheric CO2 (ppm)
- ALOHA seawater pCO2 (in situ)
- ALOHA seawater pH (in situ)

**Year**

- 1958
- 1970
- 1982
- 1994
- 2006
- 2018

**pCO2 (ppm)**

- 275
- 300
- 325
- 350
- 375
- 400
- 425

**pH**

- 8.33
- 8.31
- 8.29
- 8.27
- 8.25
- 8.23
- 8.21

**Emiliania huxleyi**

- 300 (ppm)
- ~800 (ppm)

**Gephyrocapsa oceanica**

**Dissolution of pteropod’s shell**

0 days

15 days

30 days

45 days

Reibesell et al., 2000

NOAA-PMEL Carbon program
Global warming

Top down control

Bottom up control

Harmful Algal Blooms (HABs)

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

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
**Karlodinium veneficum**

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

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

**Heterosigma akashiwo**

**Chattonella subsalsa**

Place et al., Harmful algae (2012)

Engesmo et al. (2016), Phycologia

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 °C while raphidophyte toxicity was higher at 25-28 °C.
- **K. veneficum** had greater hemolytic activity and raphidophyses 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
- \( \sim 100 \, \mu\text{mol} \, \text{photons} \, \text{m}^{-2} \, \text{s}^{-1} \)
- Turbidity
- high T (+4 \( ^\circ \text{C} \))
- 0.5 \( ^\circ \text{C} \, \text{d}^{-1} \)
- \( p\text{CO}_2 \)

**Climate change**

- pH: 7.94 ± 0.03
- TA (μ mol kg\(^{-1}\)): 2225 ± 20
- DIC(μ mol kg\(^{-1}\)): 2496 ± 121
- \( p\text{CO}_2 \) (ppm): 1072 ± 113

**Ambient**

- pH: 8.23 ± 0.03
- TA (μ mol kg\(^{-1}\)): 2225 ± 20
- DIC(μ mol kg\(^{-1}\)): 2176 ± 91
- \( p\text{CO}_2 \) (ppm): 440 ± 29

**pH-controlled cyclostats** (n=4)
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
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.
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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 CO2 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.

https://www.bccic.ca/why-1-5oc-matters/
https://www.ipcc.ch/sr15/chapter/summary-for-policy-makers/
Experimental design

Air supply → air → Air to the CO2 remover → CO2 free air → CO2 remover

CO2 supply

pH = SP pH
pH > SP pH → open CO2 valve
pH < SP pH → open CO2 free air valve