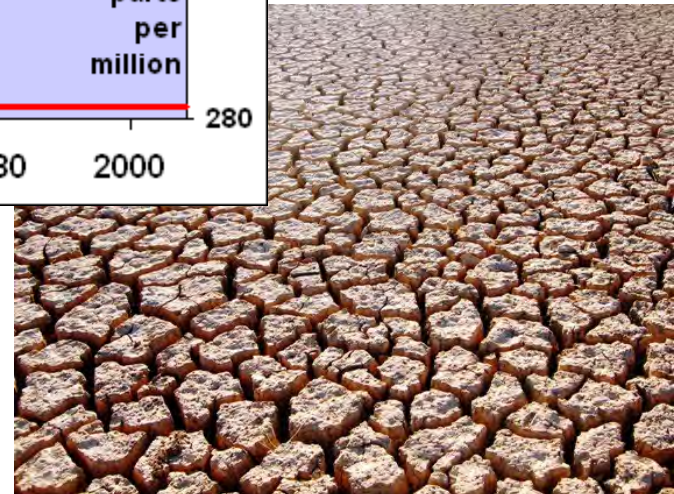
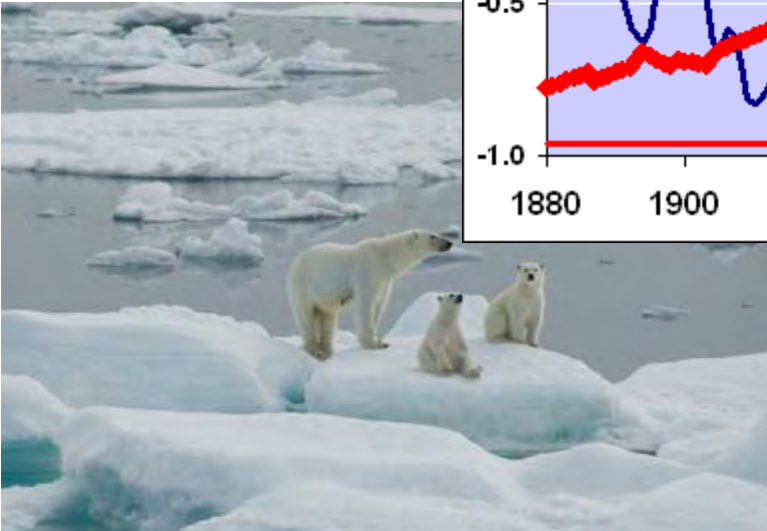
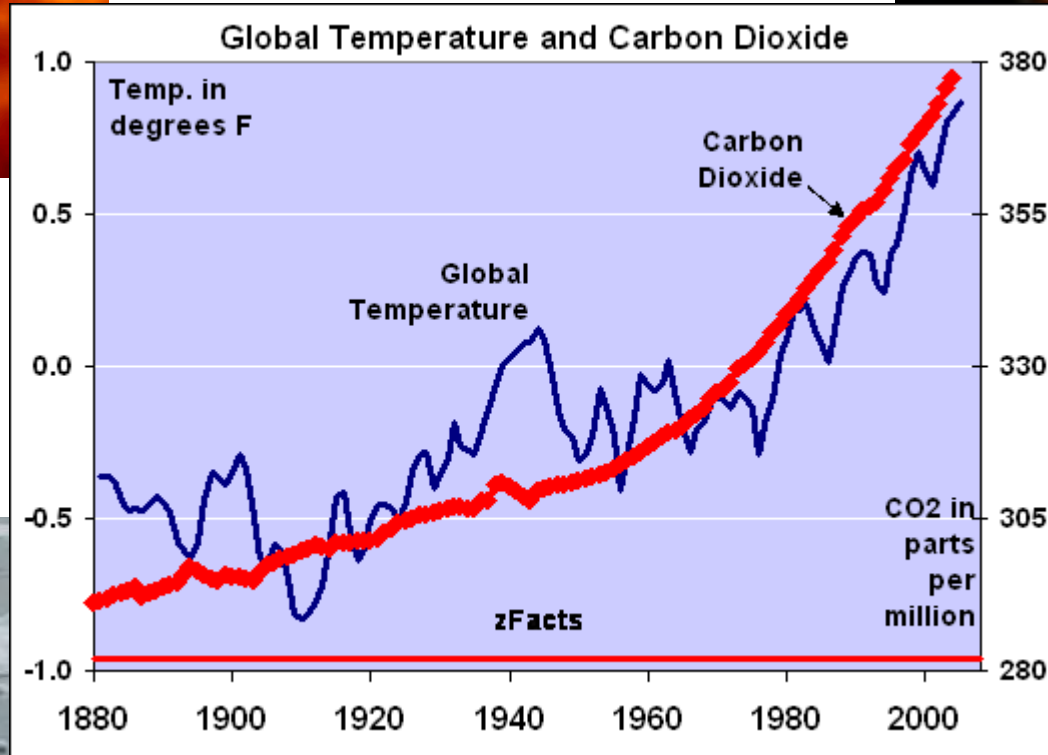
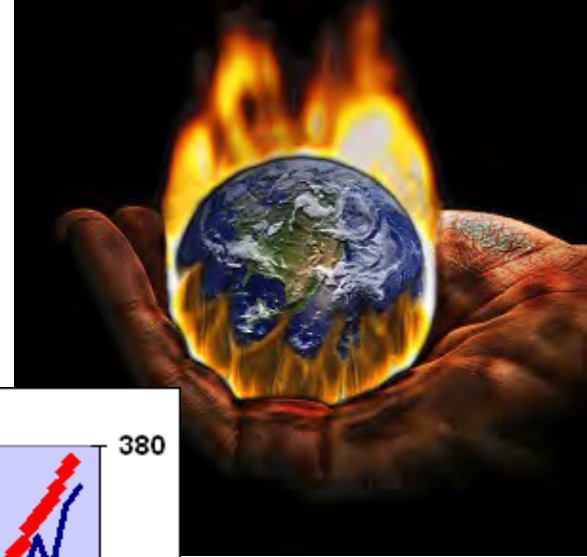
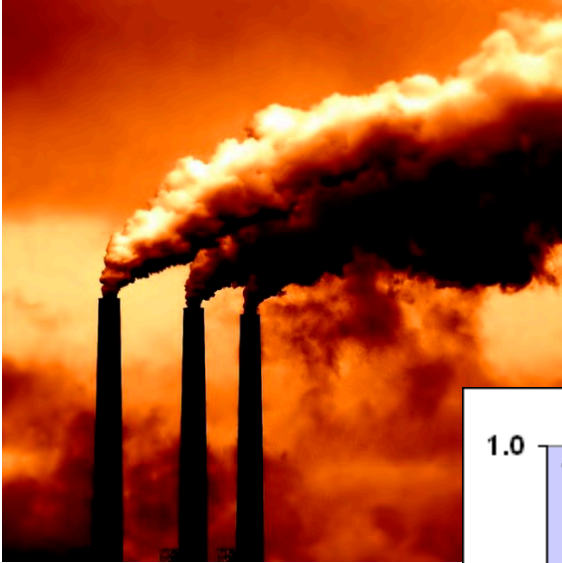


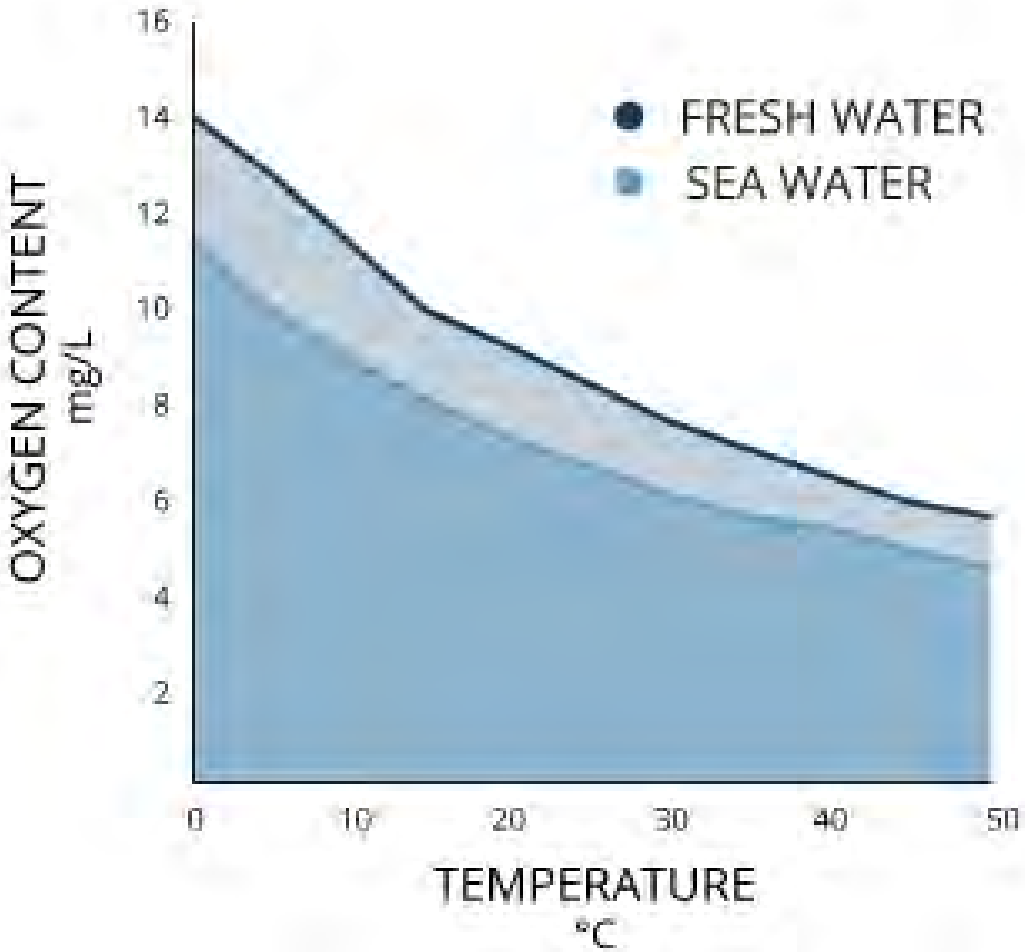
# **Effects of temperature increase and oxygen decrease on behavior and physiology of marine benthic invertebrates**

Taewon Kim, Boongho Cho, Eunchong Sin  
Department of Ocean Sciences  
Inha University  
Republic of Korea

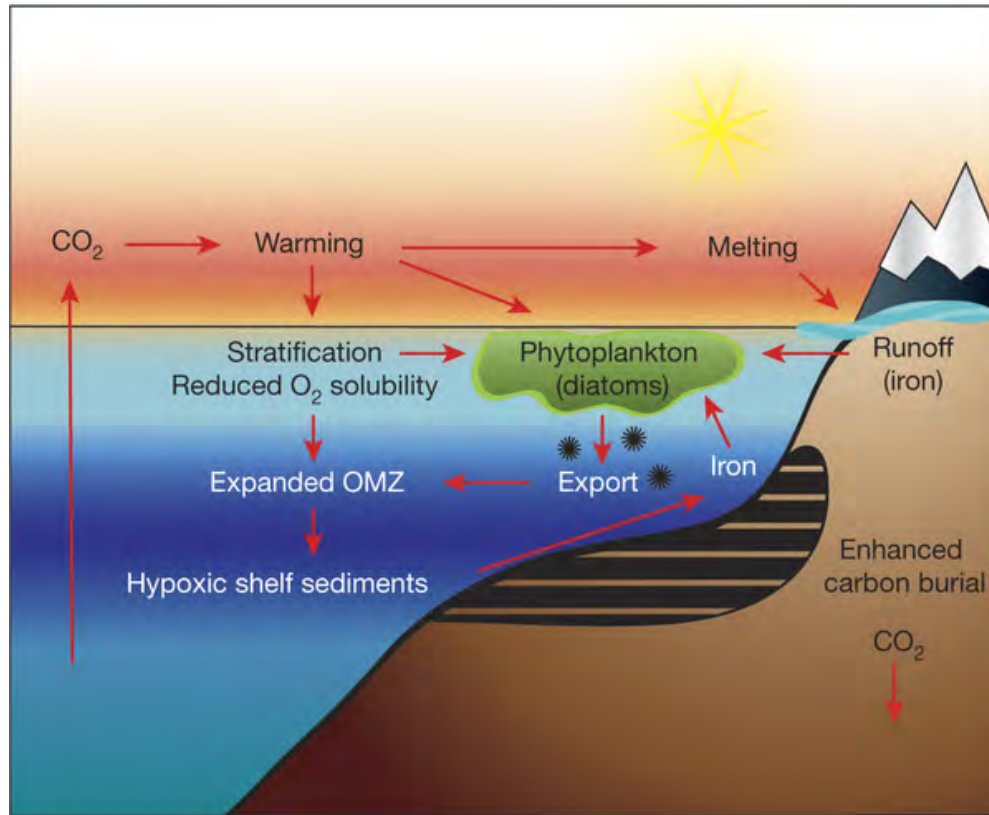




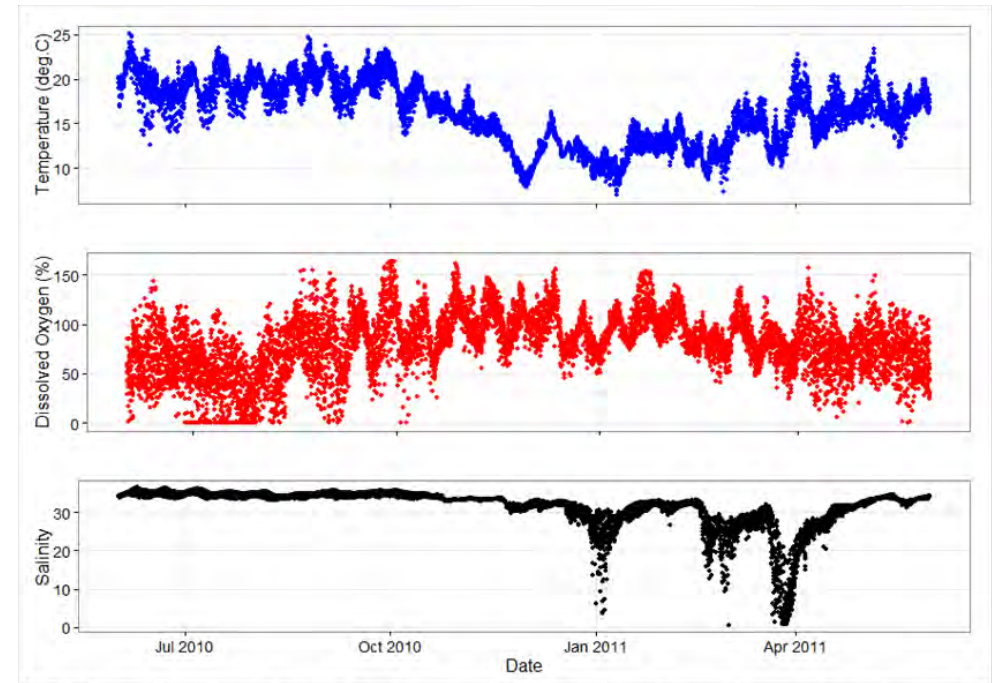
# Oxygen solubility in water vs. temperature



# Warming and Hypoxia



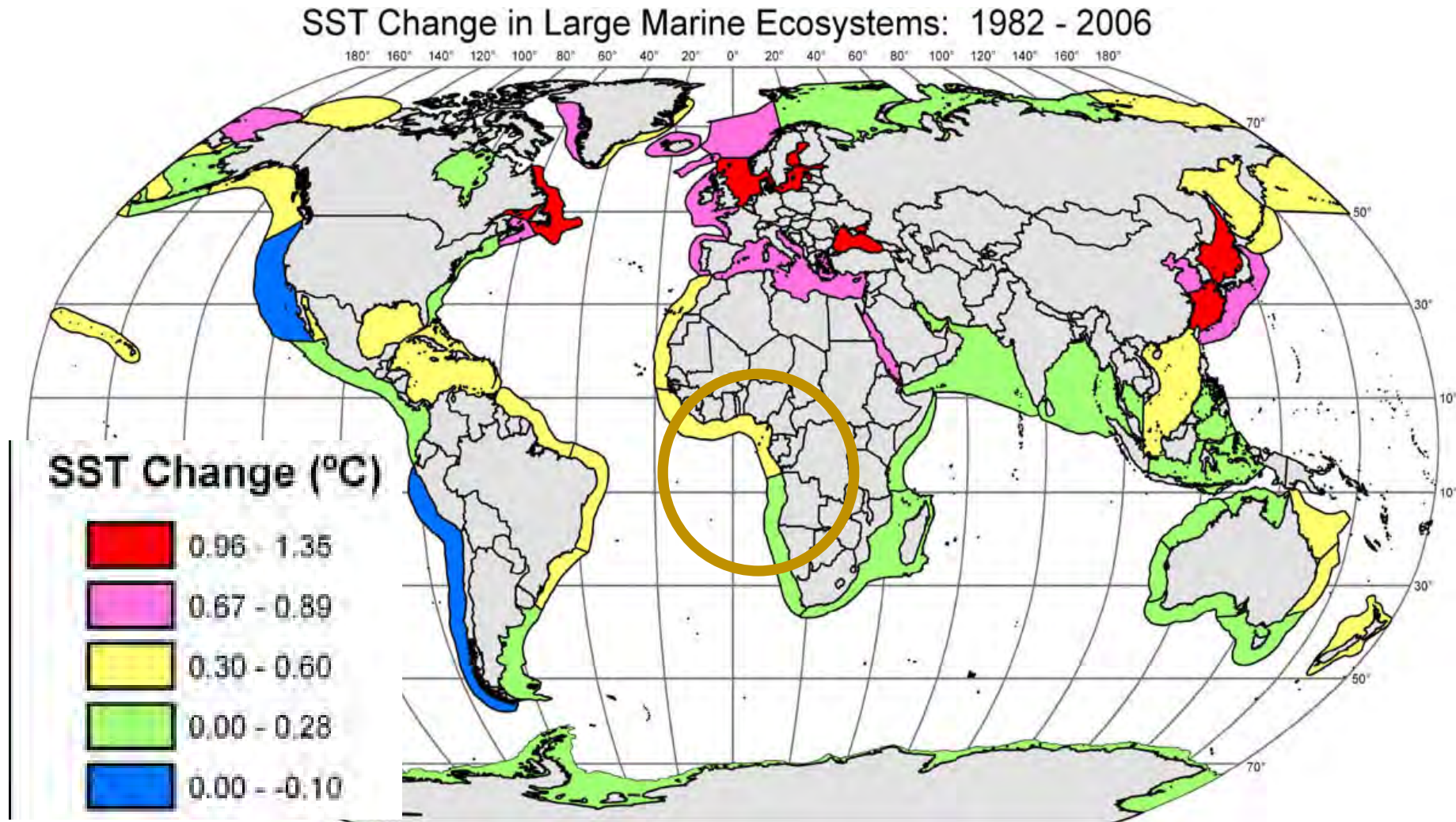
Praetorius et al. (2015) Nature



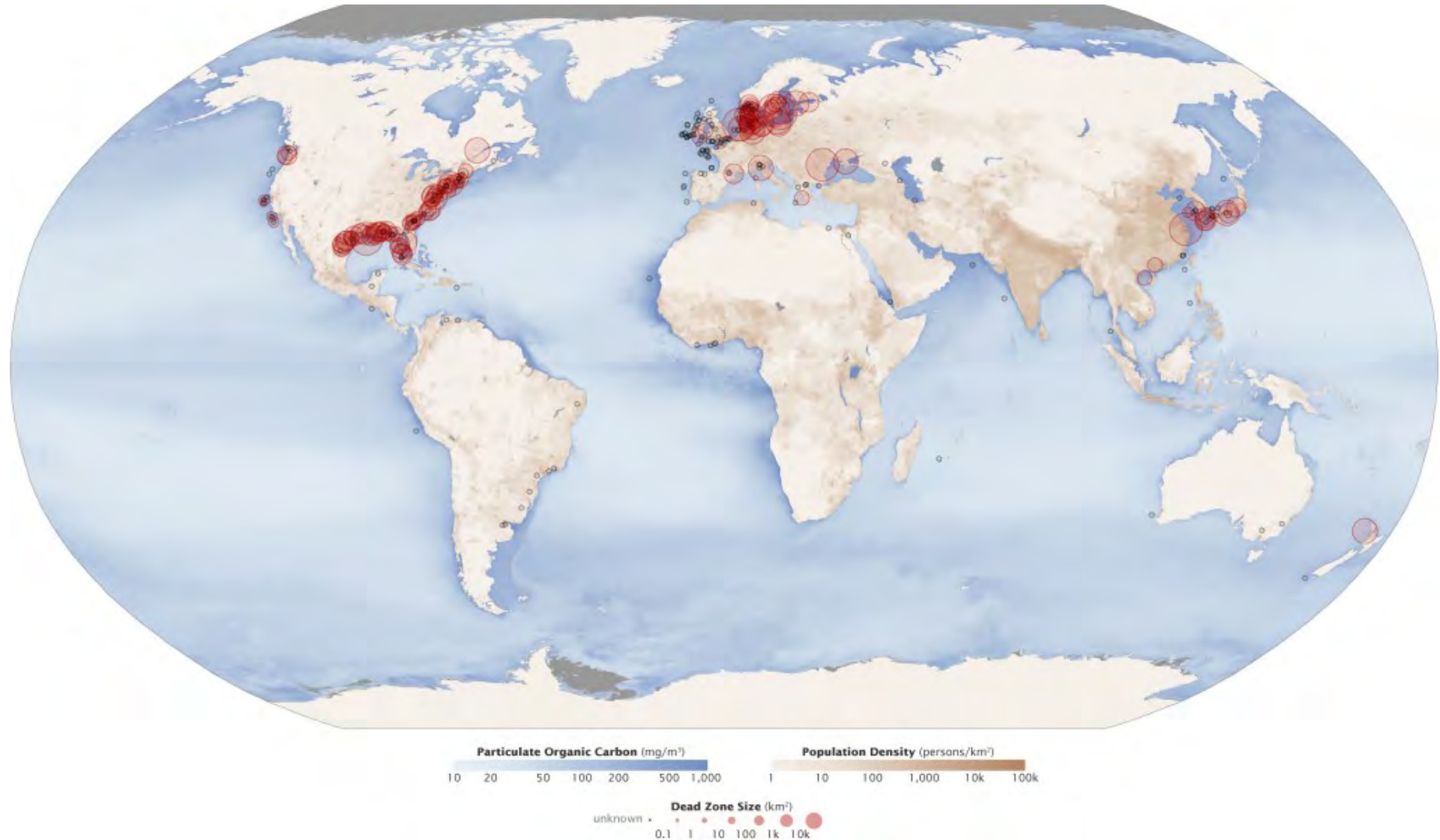
Physical stressors within estuaries such as Elkhorn Slough vary over multiple time-scales and act upon differing life stages of resident species.

Cheng et al. (2015) Global Change Biology

# Net SST Change in Large Marine Ecosystems

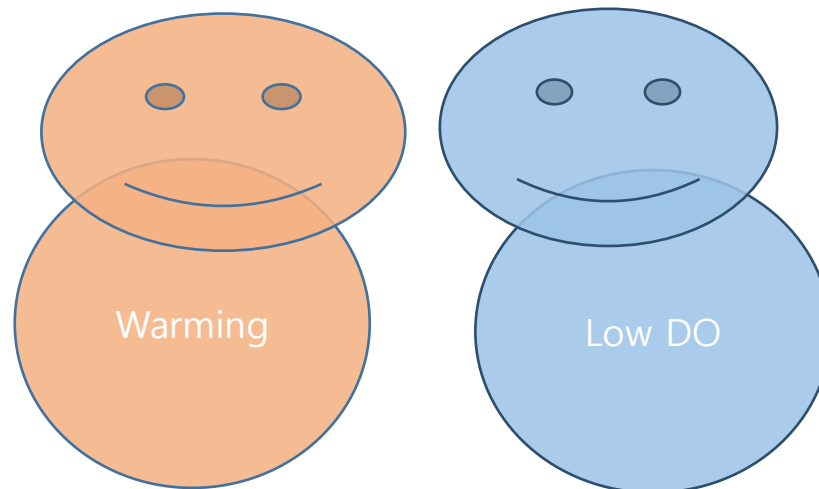


# Hypoxic zones around the world



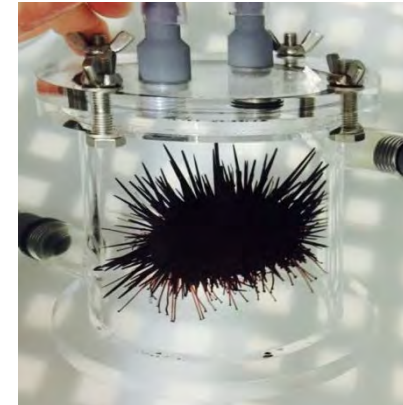
From NASA

What is the effect of increase in temperature and deficiency in DO on behavior and physiology of marine benthic invertebrates?



# Temperature & DO controlling experiment (2x2 factorial design)

|                              | Low DO<br>(3-4 mg/L, 40~50%<br>saturation) | Normoxia<br>(7-8 mg/L, 85~<br>100% saturation) |
|------------------------------|--|--|
| High temp (23-24°C)          | High temp. & Low<br>DO                     | High temp. &<br>Normoxia                       |
| Control temp (18.5-<br>20°C) | Control temp. & Low<br>DO                  | Control temp. &<br>Normoxia                    |





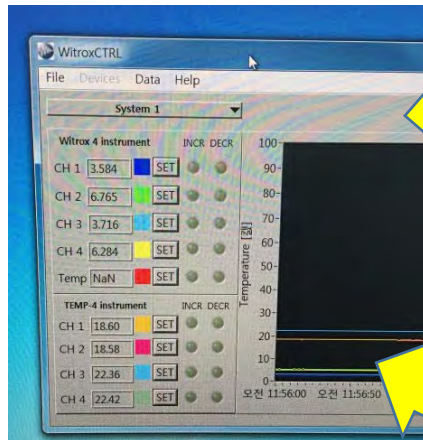
# Regulation of DO and temperature



N<sub>2</sub> gas



MFC regulator



DO control (Witrox Ctrl)

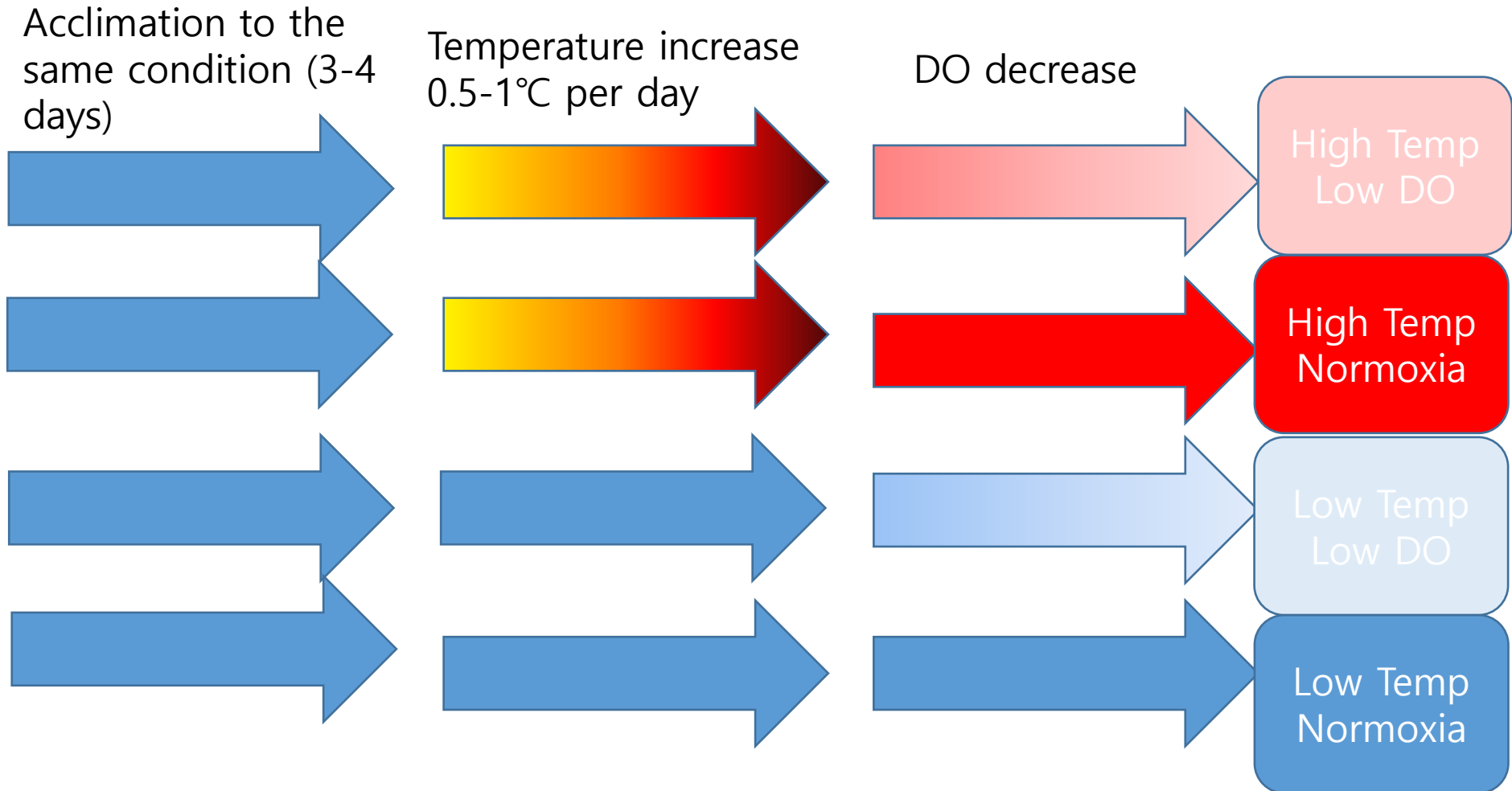


Temp & DO sensor monitor



Aquarium  
(with coolers and heaters)

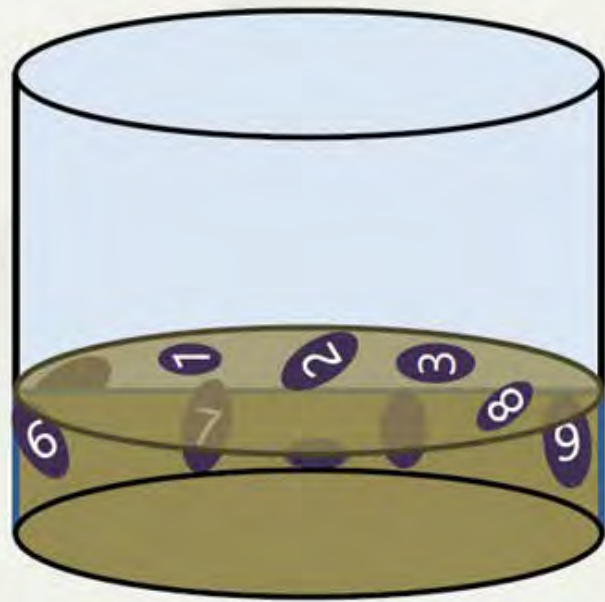
# Temperature and DO change schedule





Case study 1.  
Manila clams 바지락  
(*Venerupis philippinarum*)

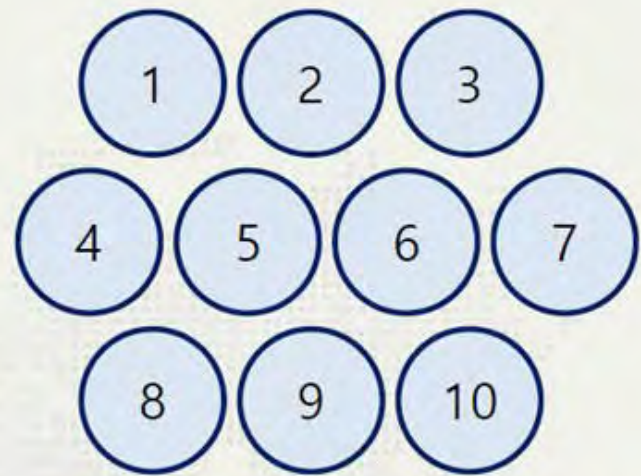




10cm

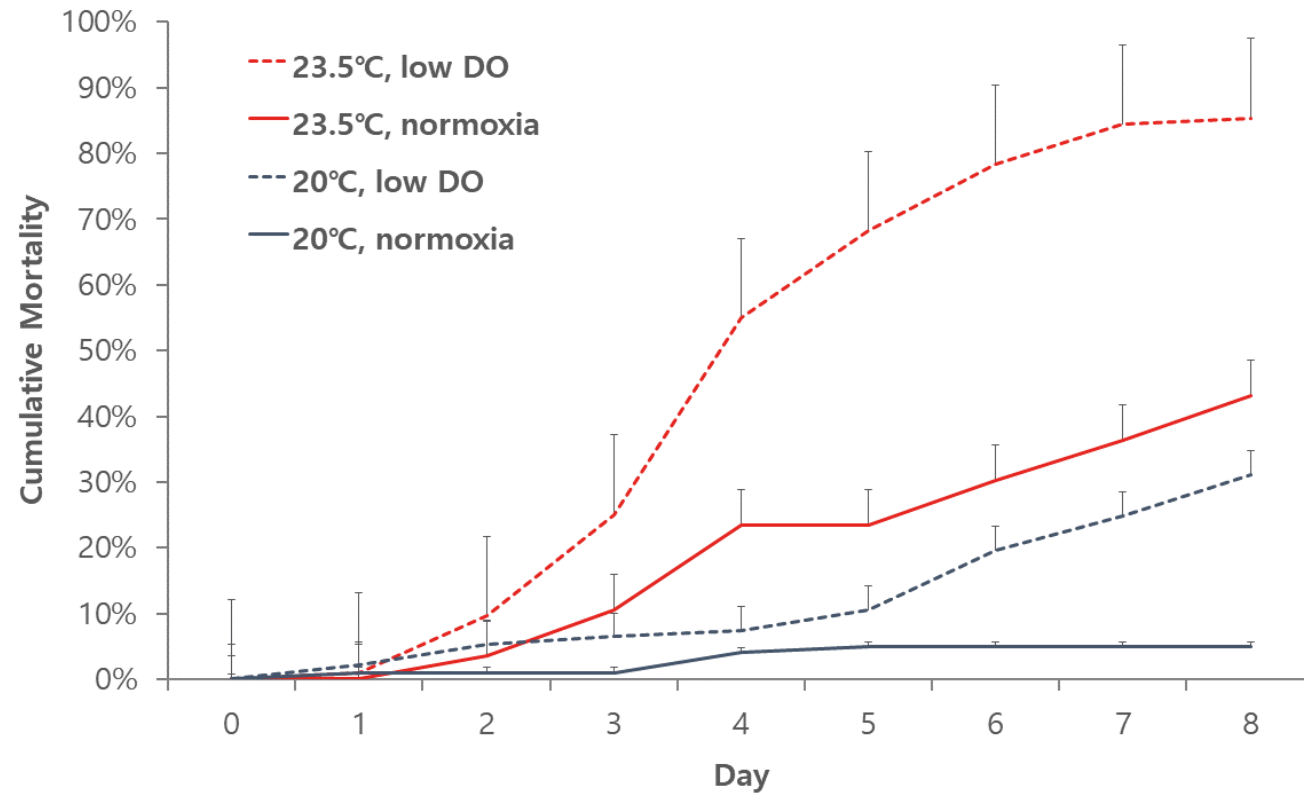


사니질토  
3cm

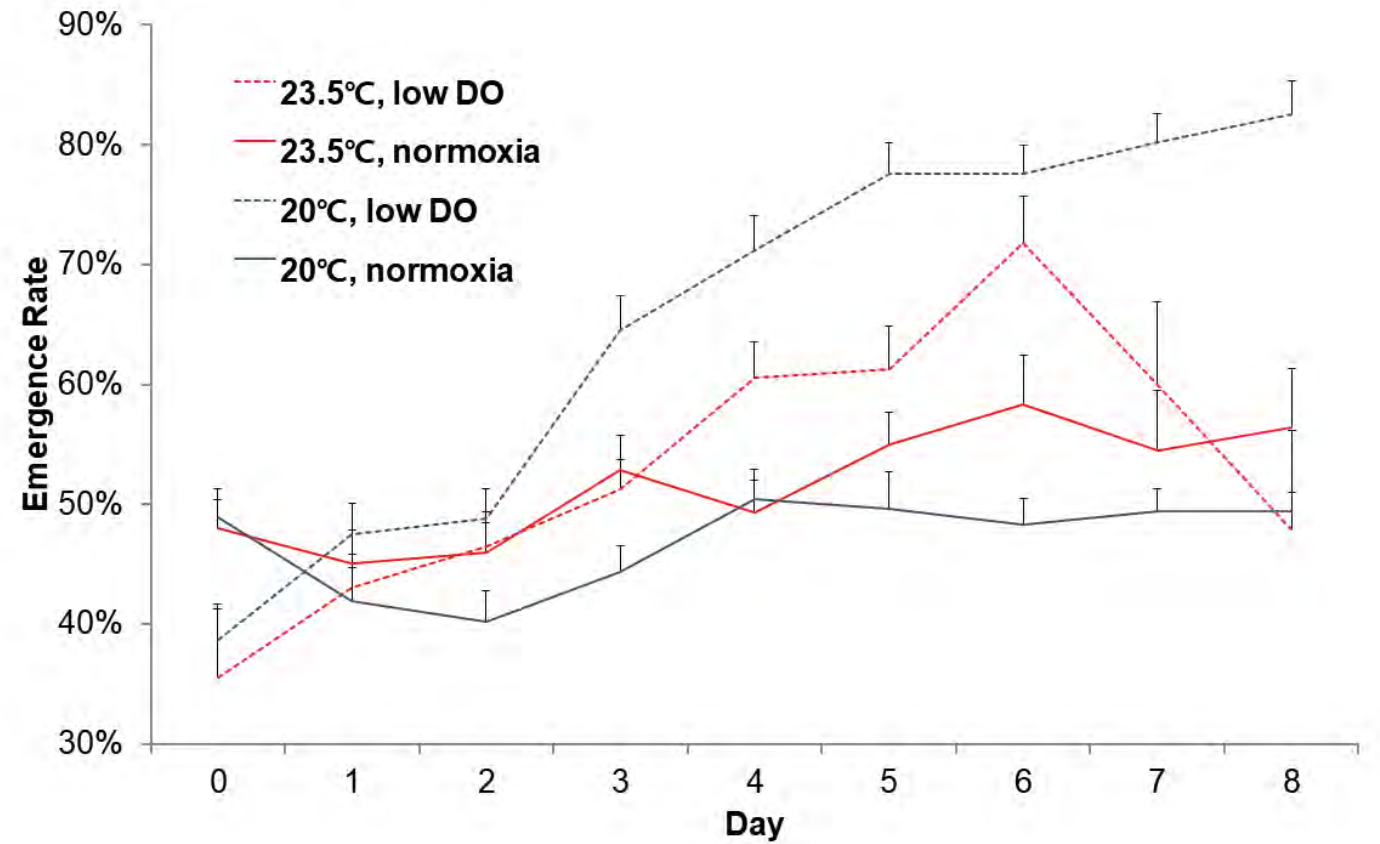


**10 Replicates**

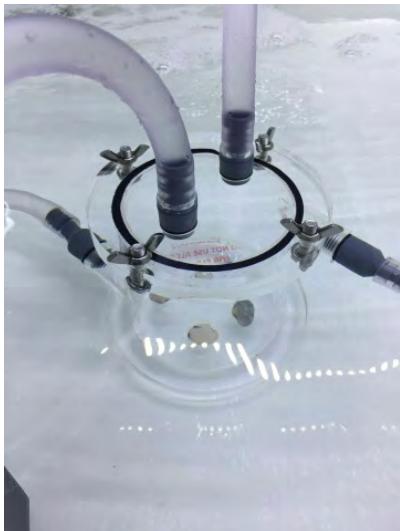
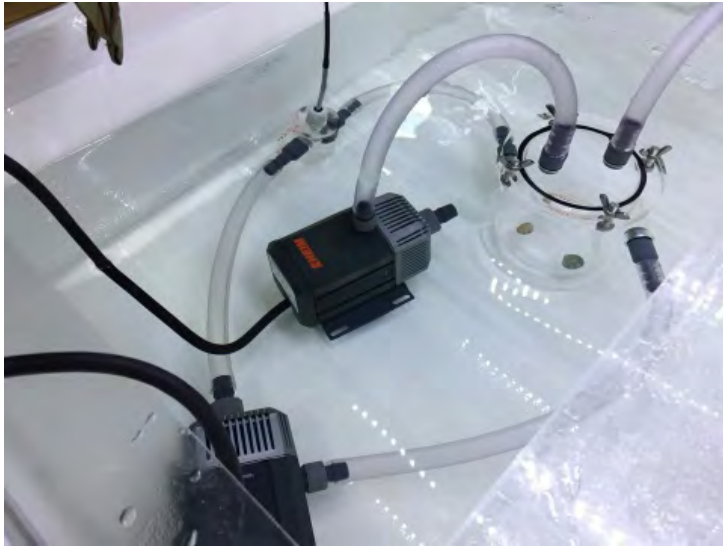
# Mortality of juvenile Manila clams



# Emerging behavior

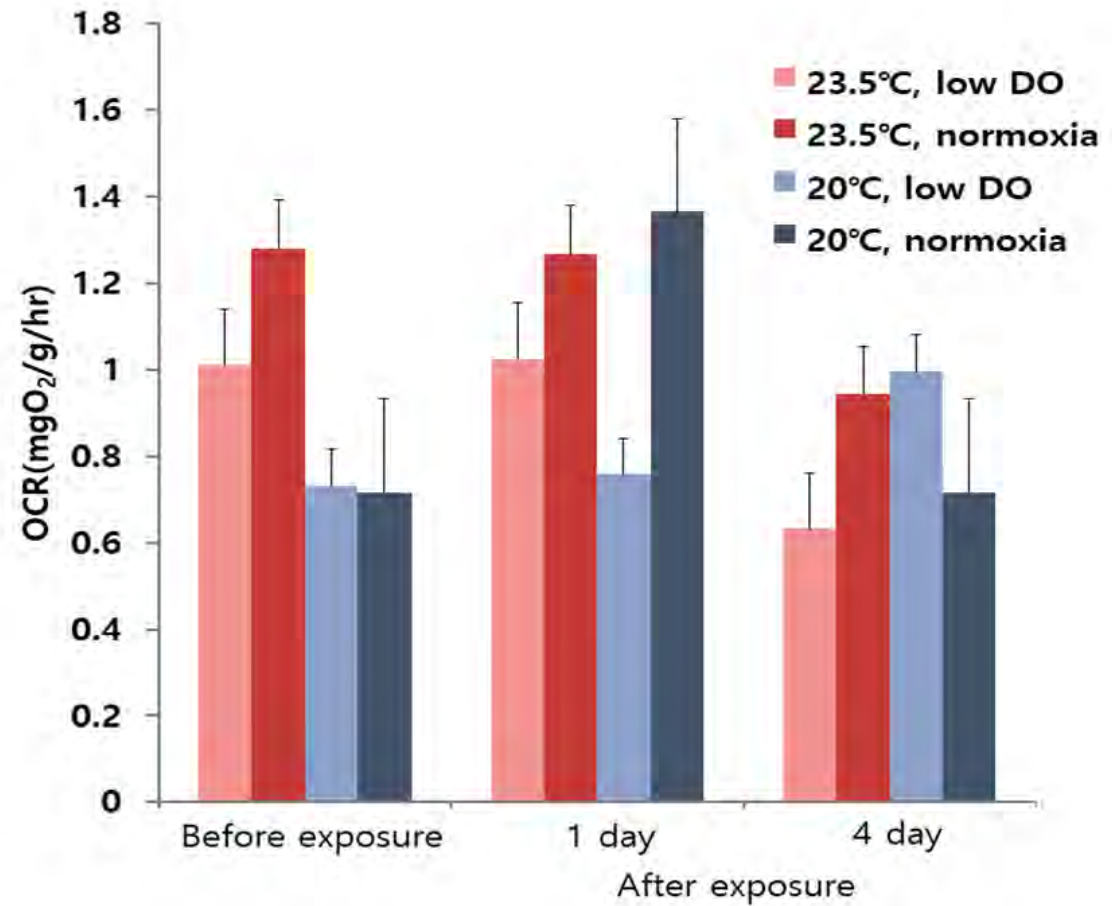


# Oxygen consumption rates



Loligo systems®  
Respirometer

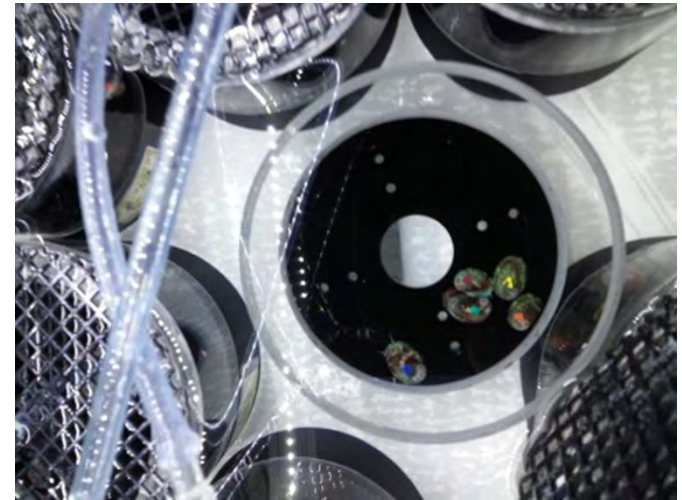
30 min. duration



Kim et al. (2018) Ecology and Evolution

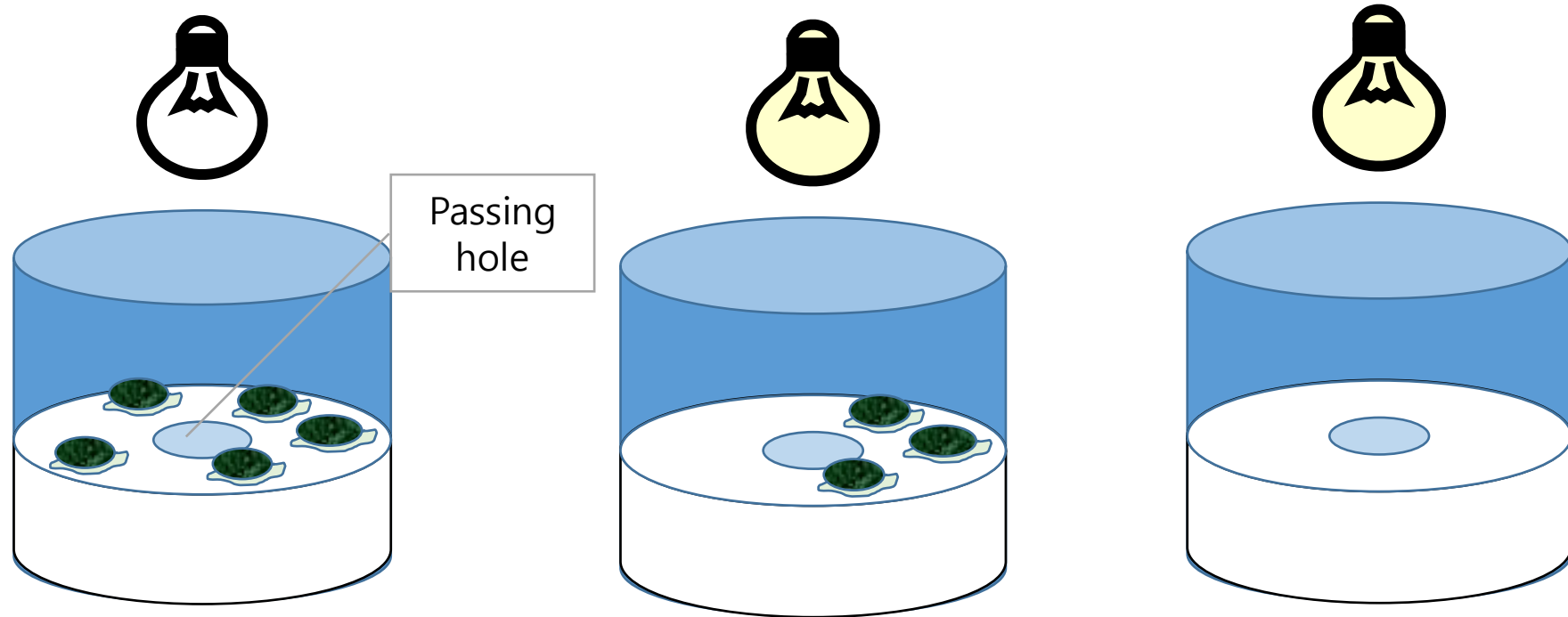


Case study 2.  
Pacific abalone 참전복  
*Haliotis discus hannai*

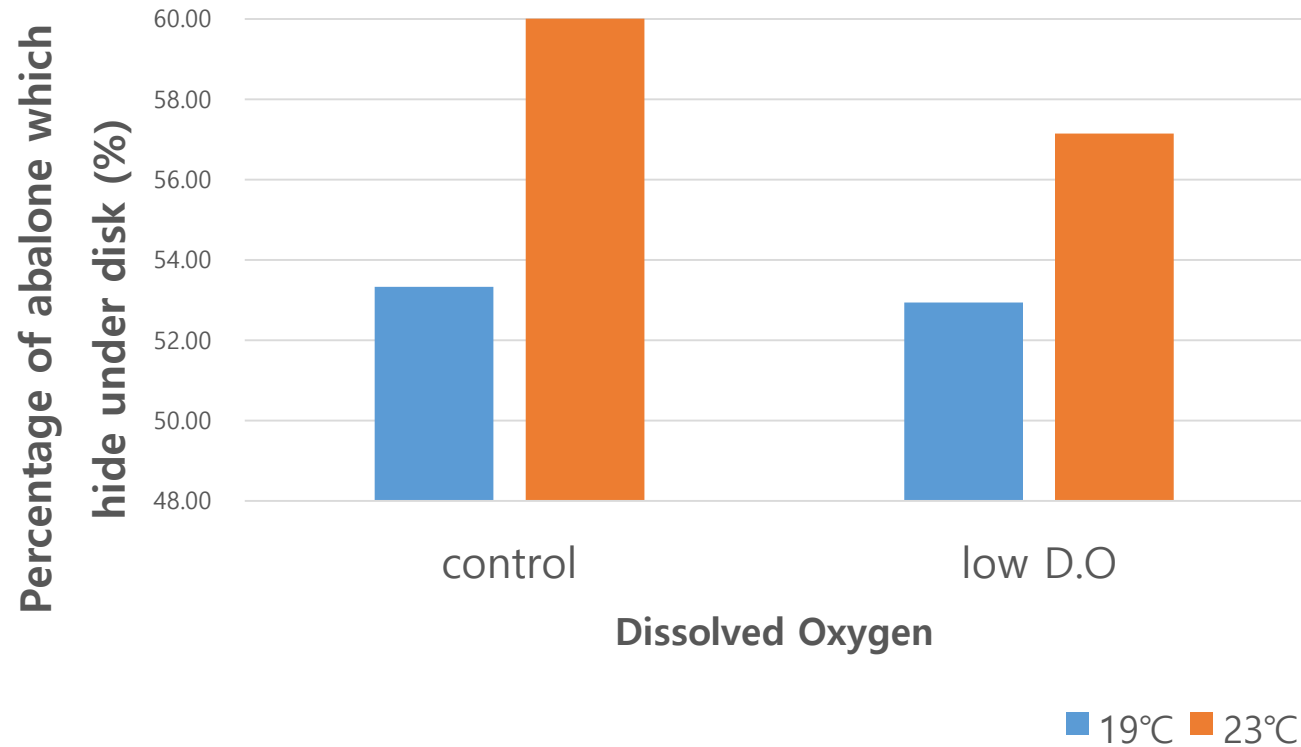




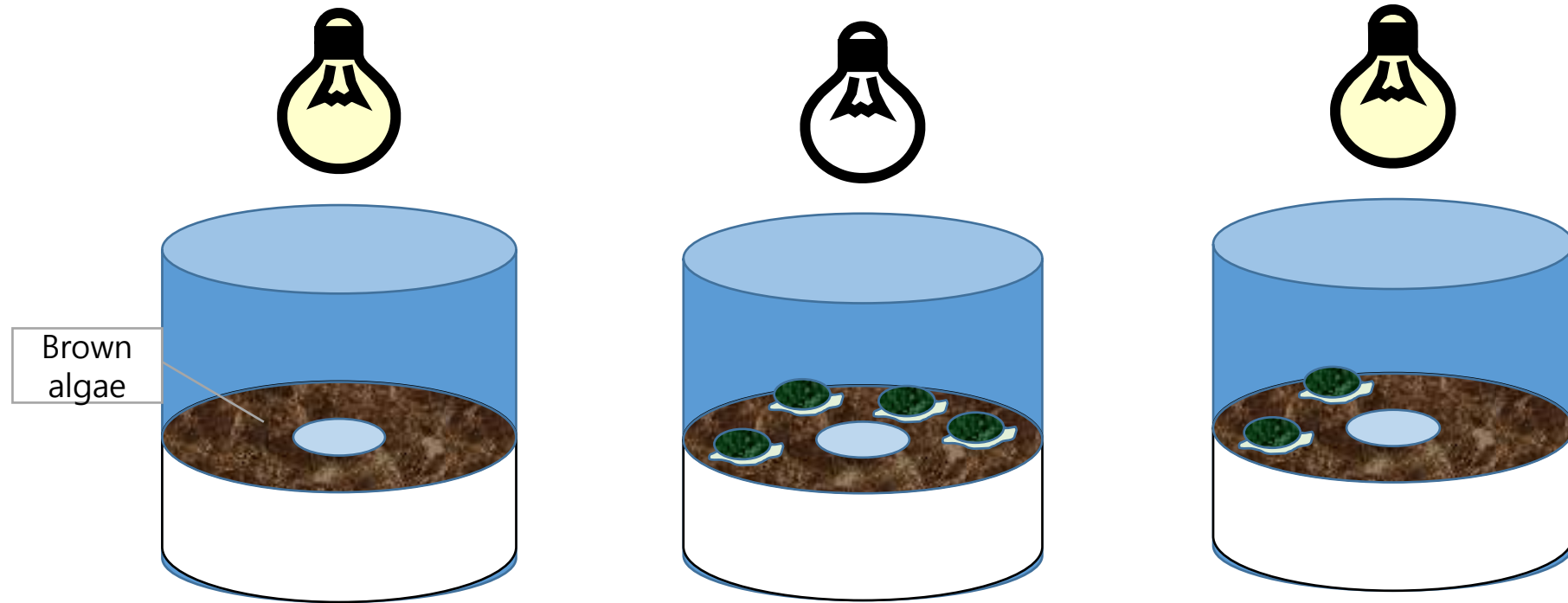
# Light (predation) avoidance experiment



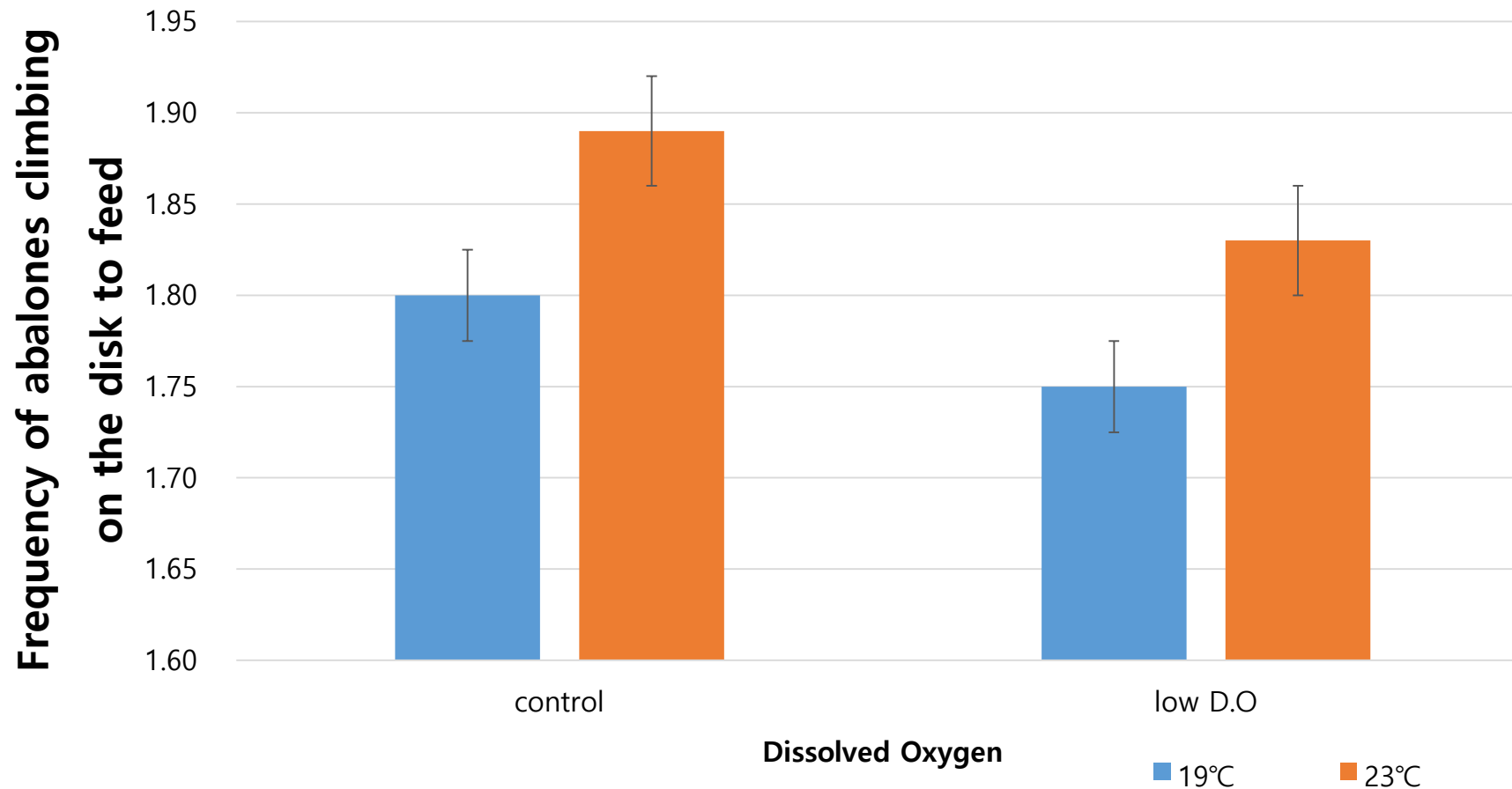
High temperature had a positive effect on light avoidance but low oxygen had a negative effect



# Foraging experiment



High temperature had a positive effect, but low oxygen had a negative effect on foraging



Case study 3.  
Sea urchins 둥근성게  
*Mesocentrotus nudus*







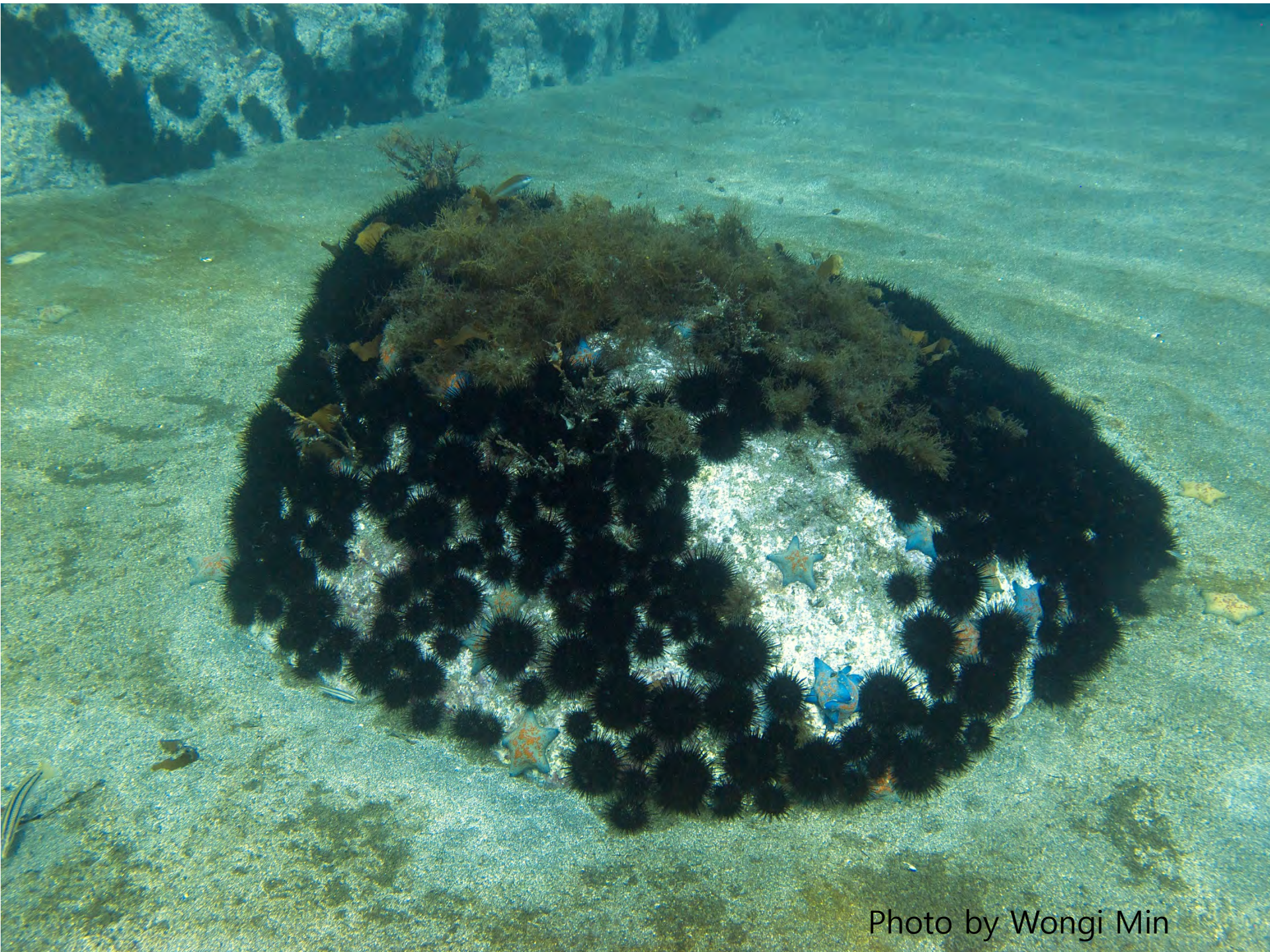
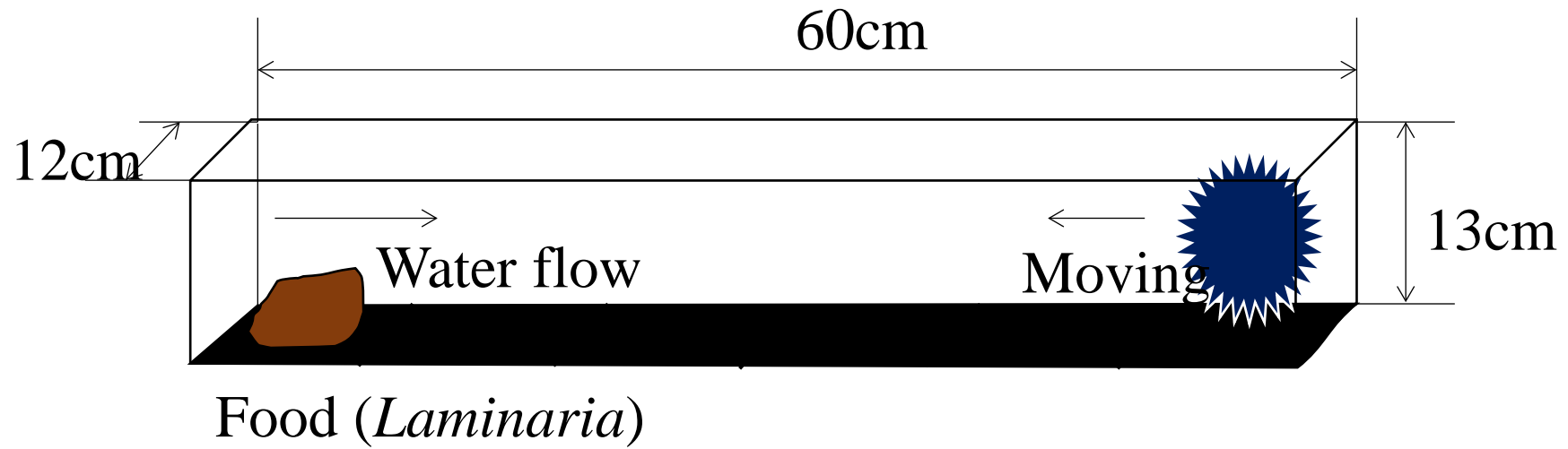


Photo by Wongji Min



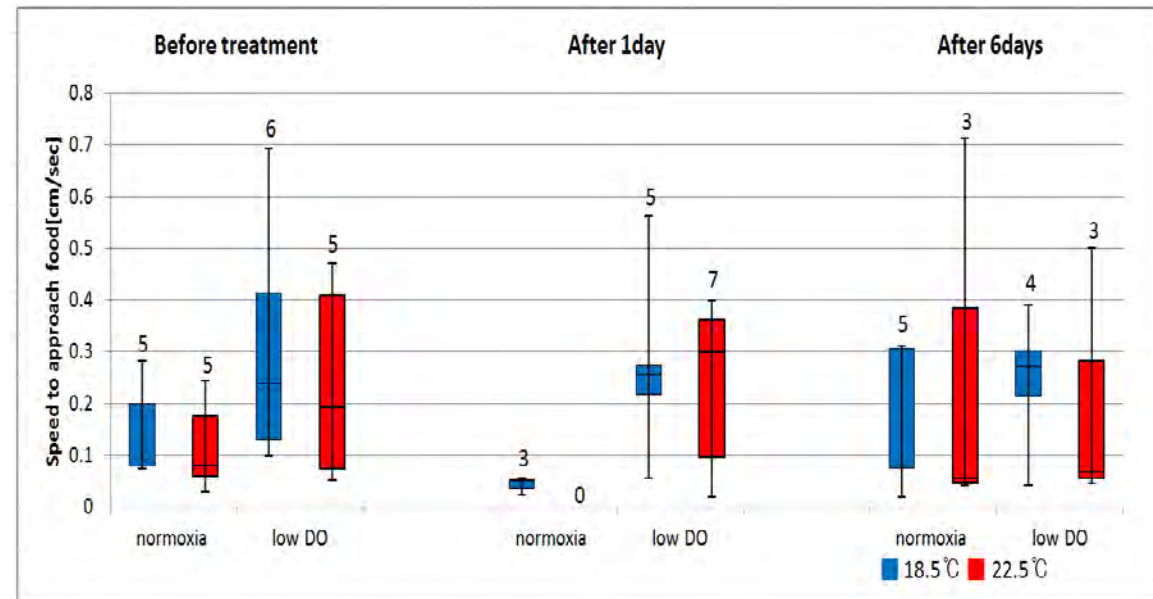
# Foraging experiment



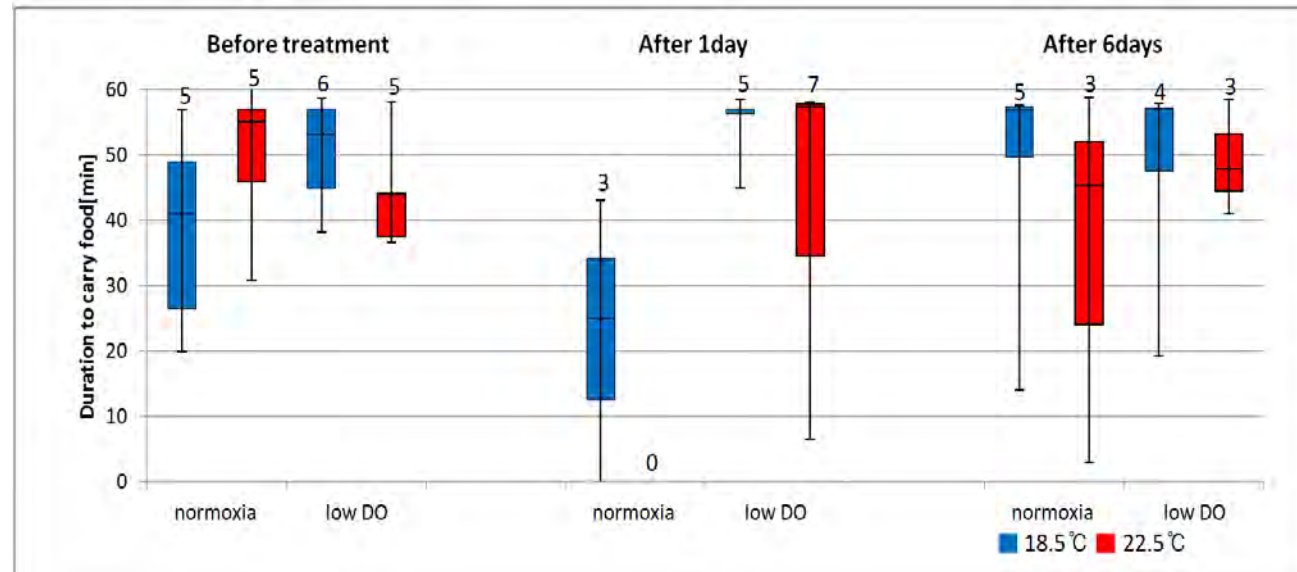
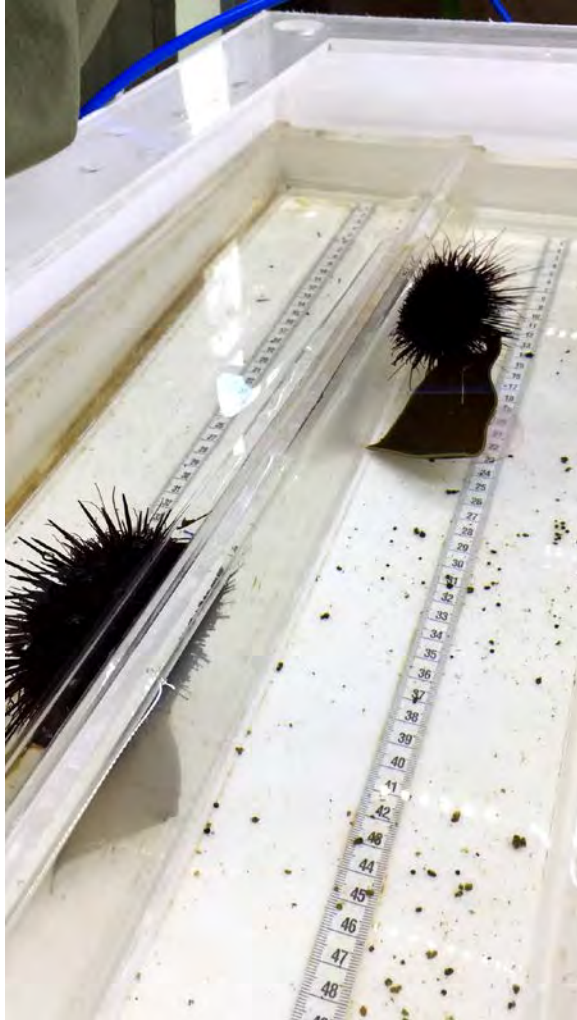
# Racing to approach food



All  $P > 0.05$

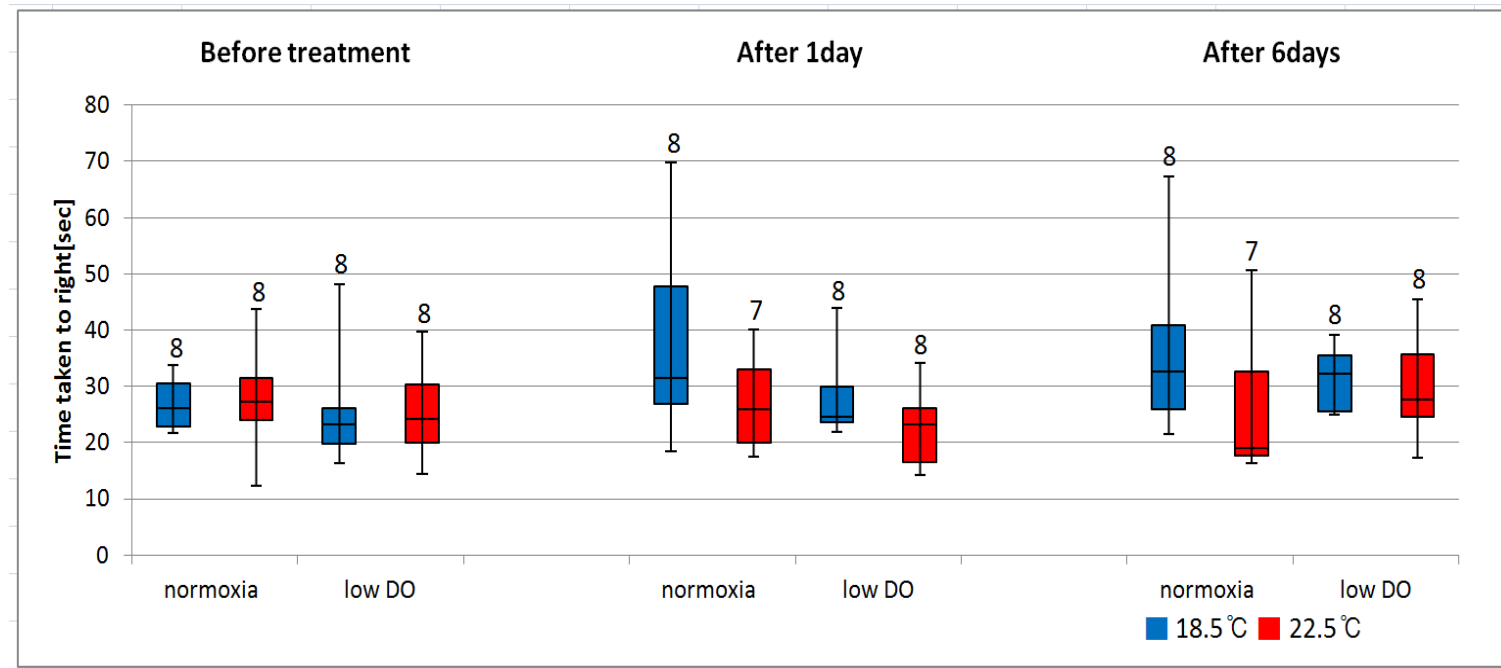


# Catch me if you can



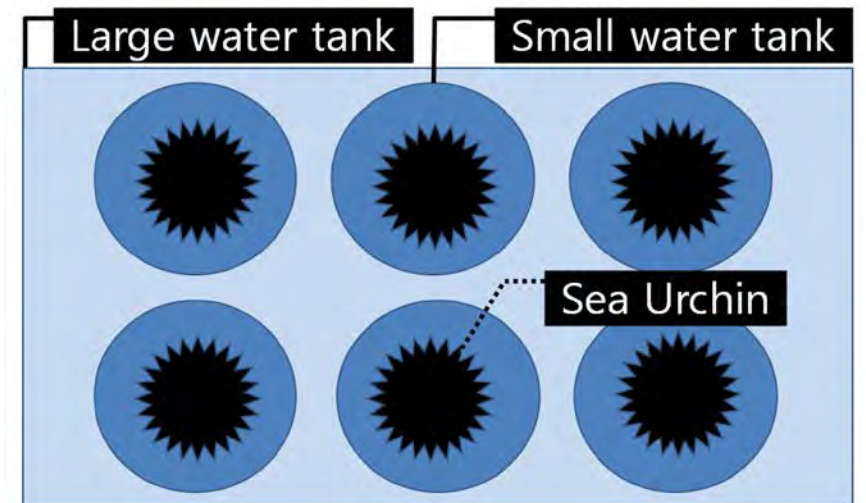
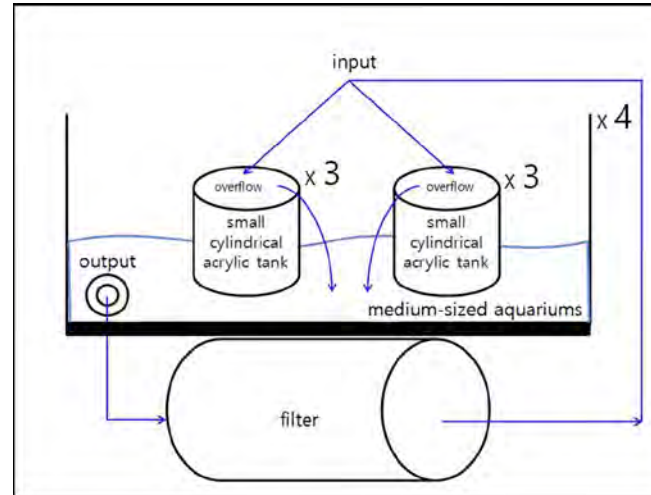
All  $P > 0.05$

# Time to get up!

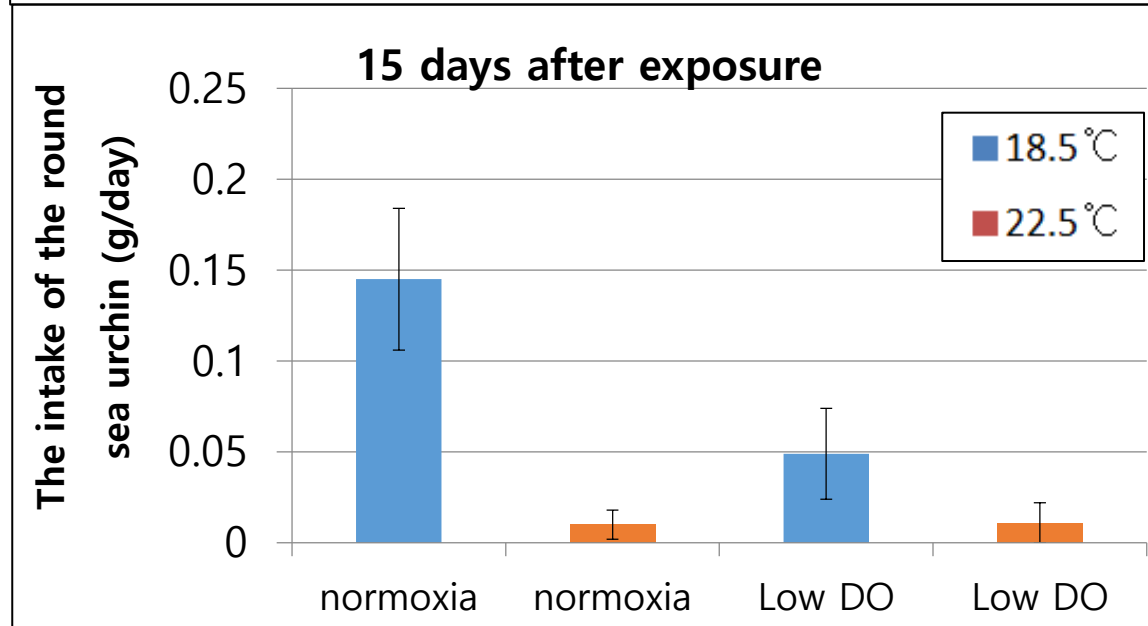
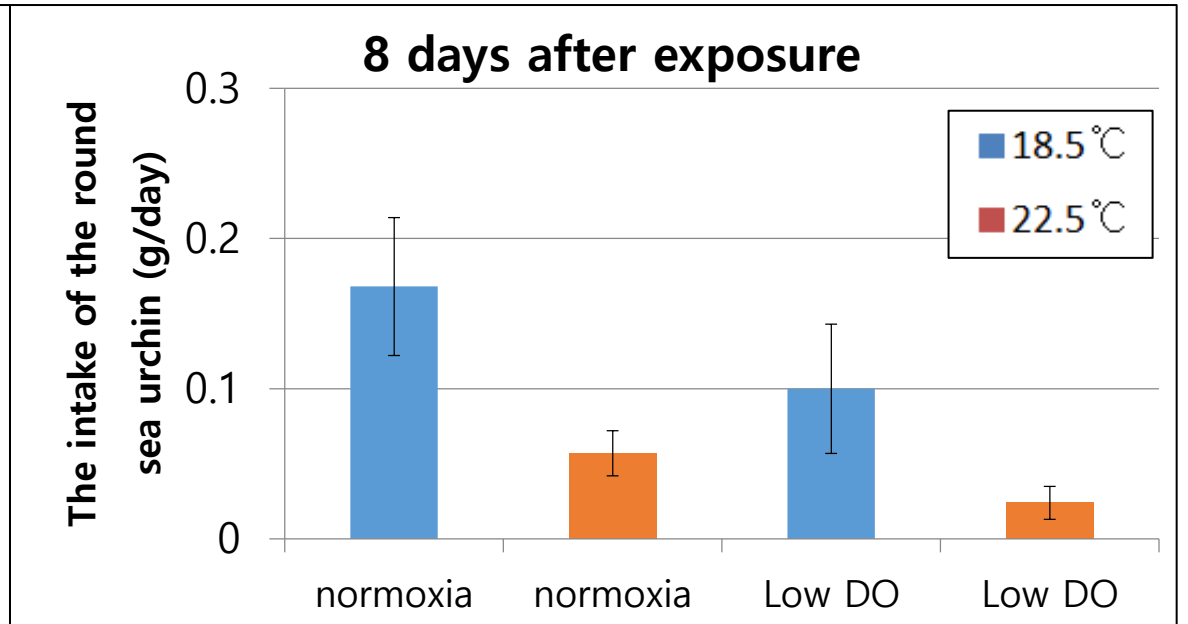
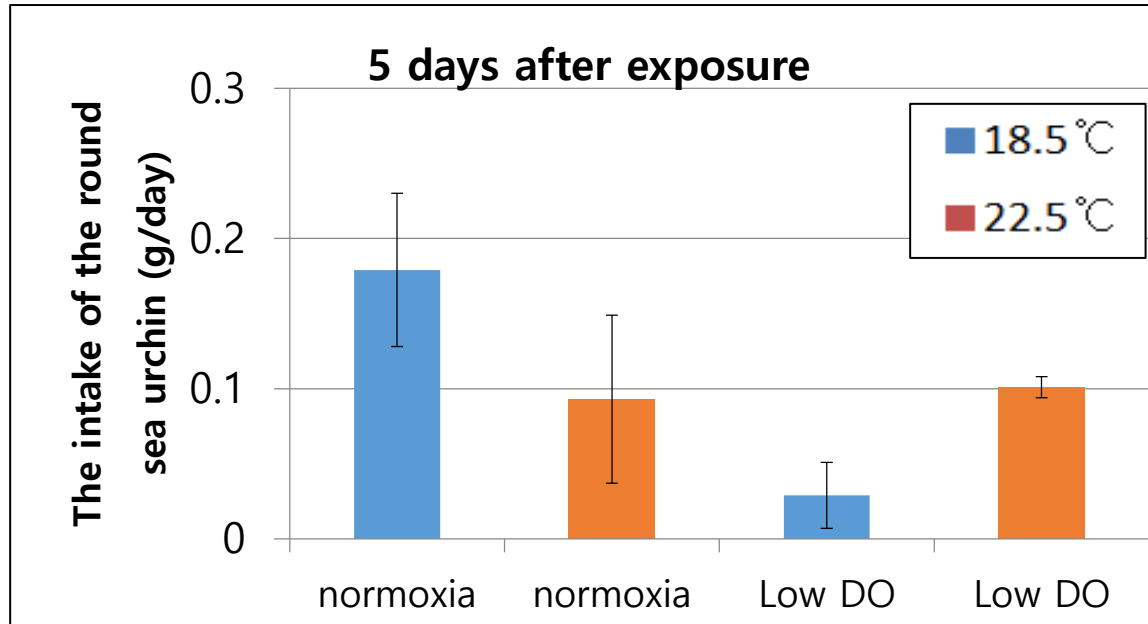


All  $P > 0.05$

# Feeding experiment



# Food intake



| Source of Variation          | Mean Square | F     | P-value |
|------------------------------|-------------|-------|---------|
| Temperature                  | 0.072       | 7.655 | 0.012   |
| DO (Dissolved Oxygen)        | 0.058       | 6.246 | 0.021   |
| Interaction (Temperature*DO) | 0.041       | 4.384 | 0.049   |



# Summary

- **Responses of benthic invertebrates to increased temperature and decreased DO vary depending on species.**
  - **Increase in temperature and decrease in DO have additive negative effects** on juvenile Manila clams in terms of mortality.
  - **Temperature increase is beneficial** but **low DO is detrimental** to juvenile Pacific abalone in terms of foraging and predation avoidance.
  - Adult sea urchins are tolerant to increase in temperature and decrease in DO in terms of foraging behavior and righting ability but their **feeding amount was reduced by high temperature and low DO.**

# Acknowledgements

- We thank Shinyeong Park, Chaeyung Yu, Hana Ju, and Young Jin Lee, Serim Lim for assistance for lab experiment.
- We thank Dr. Wongi Min for collecting sea urchins for the experiment and Gil-Ah Jeong and Dr. Youn Ho Lee for identifying species.
- This study was supported by National Research Foundation Grant and KIOST.

Coming soon (Next PICES meeting)!

# How ocean freshening and acidification influence marine benthic animals in the Antarctica?

