Effects of ocean acidification on the physiological profiles in the Japanese pearl oyster *Pinctada fucata*

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Cumulative carbon sources and sinks over the last two centuries

**Sources**
- Land-use change: 160 Pg C (31%)
- Fossil emission: 348 Pg C (69%)

**Sinks**
- Atmospheric accumulation: 234 Pg C (46%)
- Terrestrial sink: 147 Pg C (29%)
- Ocean sink: 127 Pg C (25%)

Ocean is the largest sink of atmospheric CO$_2$.
These unprecedented changes...

- By the prediction of IPCC, under business-as-usual scenario, the pCO$_2$ will reach to 1,000 μatm by the end of this century.
- This will decrease pH by 0.3-0.4 unit, as well as decrease the $\Omega_{\text{calcium carbonate}}$, and shrink the marine regions for calcifiers deposition.
- These unprecedented changes potentially evoke dramatic challenges for marine organisms and ecosystems.
*P. fucata* is the main species for yielding pearl, which is broadly distributed in the coastal area around Japan, Korea and China. As a mollusks, *P. fucata* which lives on or in the sea bad, by opening and closing their shells to filter seawater to pluck food. Provide CaCO3, and play a role as engineer.
Previous work of OA on *P. fucata*

Gene expression of OA on calcification in larvae.

*Nacrein* was believed to mediate both HCO$_3$- and Ca$^{2+}$ and is deeply involved in CaCO$_3$ crystallization

Real-time PCR analysis of expression of *nacrein* in response to elevated temperature and declined pH.

Shells of *P. fucata* showed exposed to acidified seawater revealed malformation and dissolution by SEM.

However, the integration of physiological effect of CO$_2$-induced acidification on *P. fucata* has not yet been elucidated by experiments and analogies.
Physiological response of the Japanese pearl oyster *P. fucata* to ocean acidification by:

1. morphological characteristics,
2. food intake,
3. metabolic adjustments: \( \dot{M}O_2 \)
4. protein synthesis: RNA / DNA ratios.
The process of Exp.

30 days acclimation
Two exp. Setups
  control (400 uatm) vs. high CO$_2$ (1,000 utam)
  12 individuals X 5 replicates X 2 treatments
Exp. Period: 7 weeks exposure
Sampling: every week sampled 1 individual from each aquarium.
The growth

*P. fucata* cultured in high CO$_2$ gained tissue mass at a slower rate than did in control, (0 vs 0.77 % day$^{-1}$), while there are no more potential impacts on shell dry weight.
Scanning Electron Microscopy (SEM) analysis

Elevated CO2 (1,000 uatm) did not affect the shell morphology during a 7-week exposure. The animals may sustain the high energetic cost to counteract the high dissolution rate which could happen in high pCO2 animals.
Mineralization = calcification – dissolution

Calcification increased
Food intake & oxygen consumption

*P. fucata* showed a depressed metabolism under the realistic levels of ocean acidification, suggest that for pearl oysters there may be a lower cost of basal metabolism, which might be a strategy under unfavorable environment On energy conservation and allocation to fitness sustaining processes
Protein synthesis

RNA/DNA ratios can be treated as environmental indices showing the eco-physiological responses and trophic interactions of environmental changes on marine organisms.
Extracellular

Acid-base variables (pH, [HCO3–], PCO2) in the coelomic plasma (extracellular fluid) of Sipunculus nudus under control conditions and subsequent hypercapnia. Note the incomplete compensation of the acidosis in the extracellular space. When exposed to CO\textsubscript{2}-induces acidification, marine organisms are proposed to excrete the redundant protons from the intra- and extracellular fluids, and these processes are usually considered to be the trigger for metabolism depression, which is usually by down-regulation of protein synthesis as well as by decrease in ATP consumption.
summary

1. The observed reduction in growth rate of somatic tissue may have been caused either by energy competition for calcification when they were not able to increase the energy input or by acclimation to elevated pCO$_2$ (measured as depressed metabolic rates and reduced RNA / DNA ratios).

2. The net outcome of these competing processes has substantiated the postulation that the elevation of pCO$_2$ to 1,000μtam may disrupt the population of *P. fucata*.

3. The high accretion of the mineralization which is occurred in the calcification site is potentially not able to sustain permanently.
Further studies

• Further studies are needed to evaluate the combined effects of elevated pCO$_2$ and its corresponding phenomenon, such as elevated temperature, hypoxia or low salinity on the growth and energy homeostasis of mollusks.