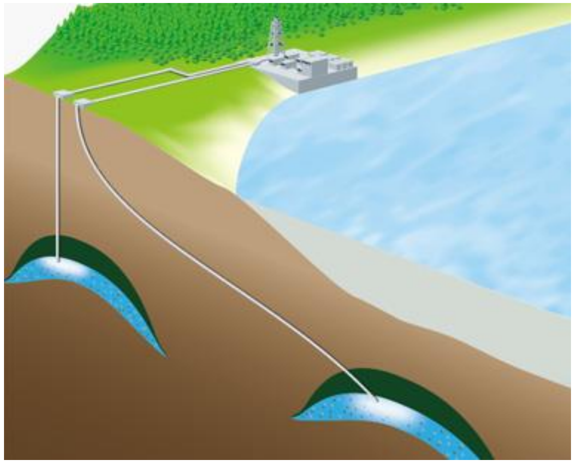
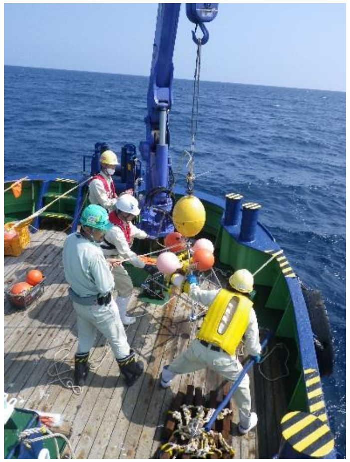
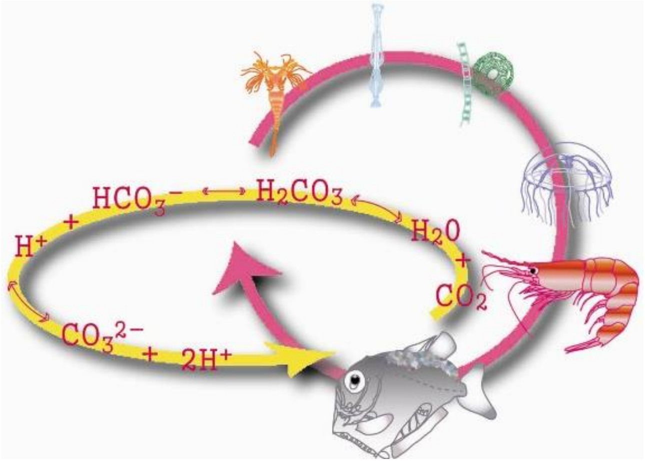
Combined Meeting of the IEAGHG Modelling and Monitoring Networks
Edinburgh Centre for Carbon Innovation
6^{th} – 8^{th} July 2016, Edinburgh, Scotland

Modelling Marine Impact

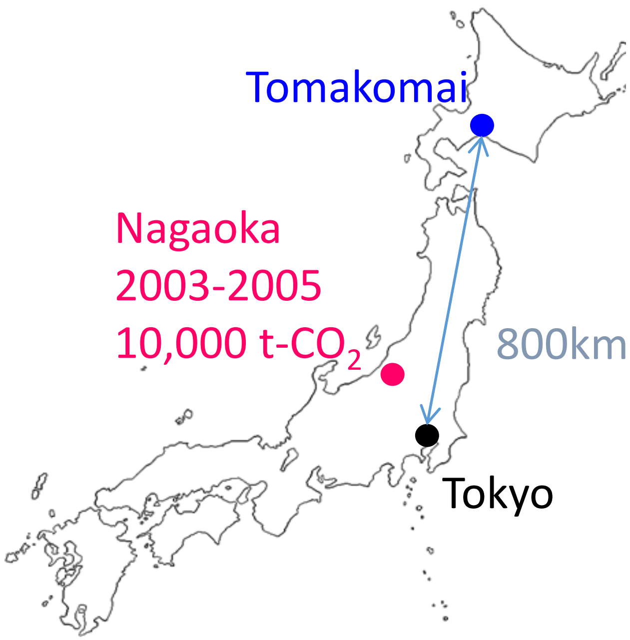






Jun Kita
Research Institute of Innovative Technology for the Earth
Marine Ecology Research Institute

Tomakomai CCS Demonstration Project



- Ministry of Economy, Trade and Industry (METI)
- Japan CCS Co., Ltd. http://www.japanccs.com
- 100,000 tonnes/year or more CO_2 is to be stored under the seabed.
- CO_2 injection will start in 2016 and continued to 2018.

Off-gas supply:
hydrogen production facility at oil refinery plant

CO_2 capture:
amine absorption

CO_2 injection:
onshore

Reservoirs:
under the seabed

- Sandstone layer: 1100-1200m depth
- Volcanic rocks layer: 2400-3000m depth

Act for the Prevention of Marine Pollution and Maritime Disasters

- May 2007: The act was amended for permit procedure on dumping CO_2 stream into sub-seabed formation.
- Prevention of marine environment impact from potential CO_2 leakage

Operator of Offshore CO_2 storage,

- Shall receive permission from environment minister.
- Shall implement Environmental Impact Assessment.
- Shall monitor surrounding sea environment.

Environmental Impact Assessment (EIA) in the ACT

Objective

- Estimation of CO_2 dispersion and its impact assessment on the assumption that stored CO_2 leaks out to the sea

Process

- Consideration of leakage scenarios and its simulation
  - CO_2 migration in the geological formation
  - CO_2 dispersion in the seawater column
- Base-line survey for the existing marine environment
- Impact assessment

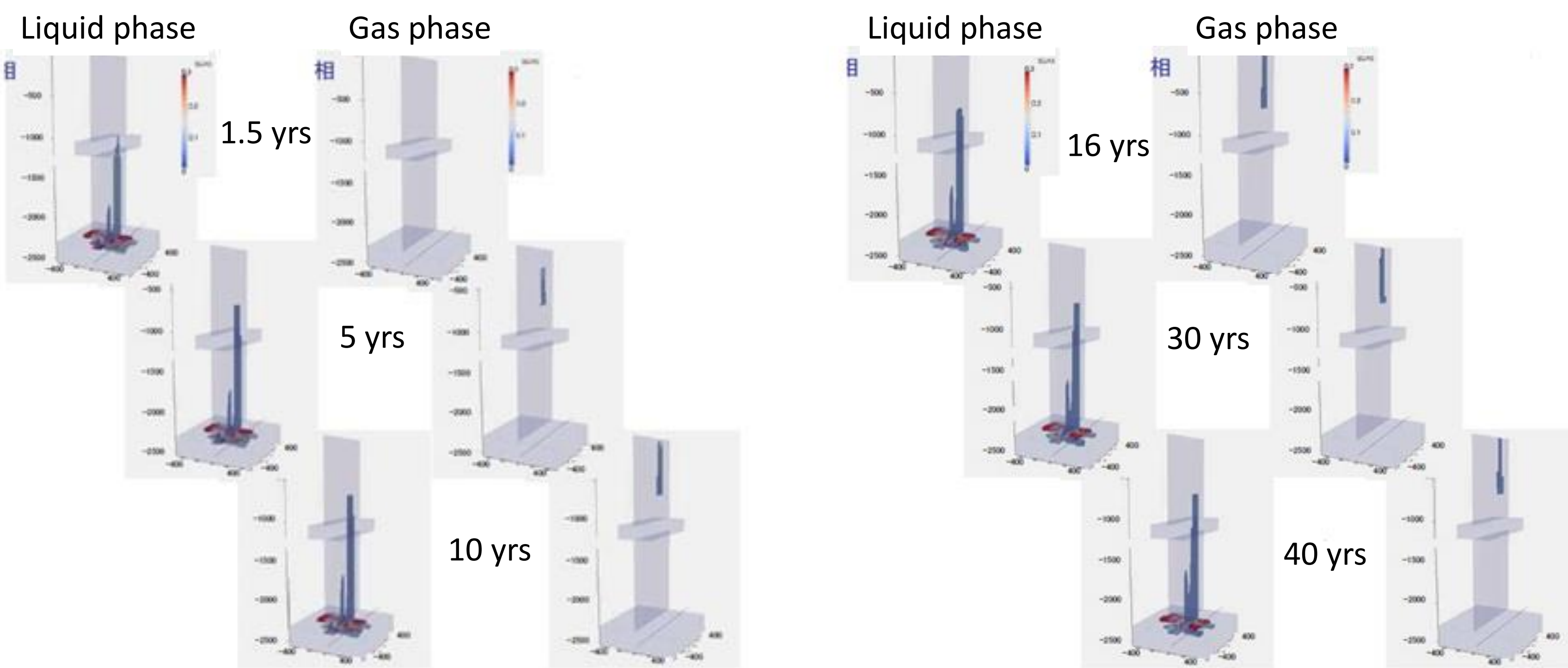
Example of leakage simulations

CO_2 migration in the geological formation

Scenario: Leakage through faults undetectable by seismic survey

Simulator: TOUGH2 with ECO2M (LBNL)

Output: CO_2 flux at the seafloor



Example of leakage simulations

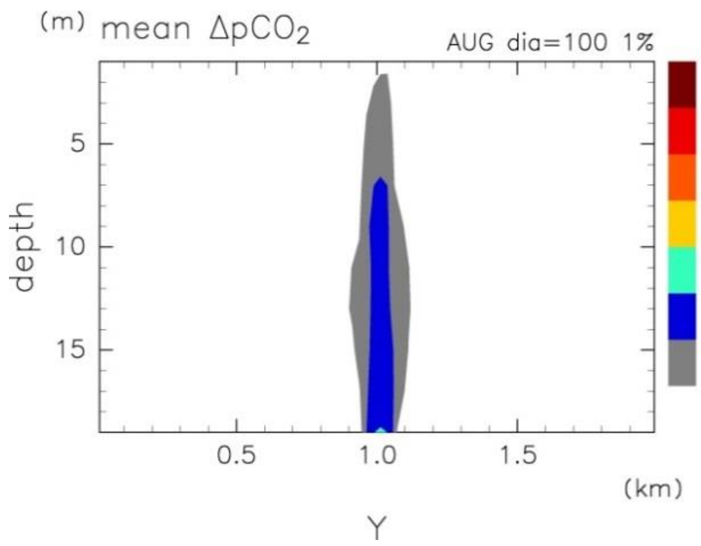
CO_2 dispersion in the seawater

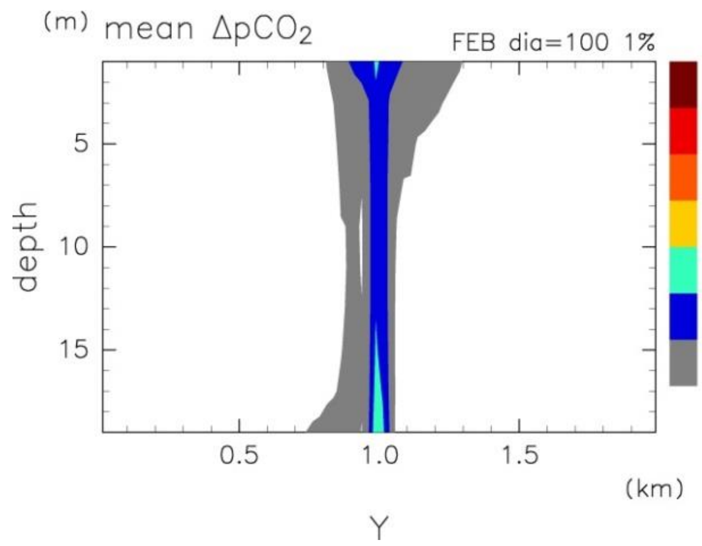
Input: CO_2 flux at the seafloor

Simulator: MEC-CO2 two-phase flow model

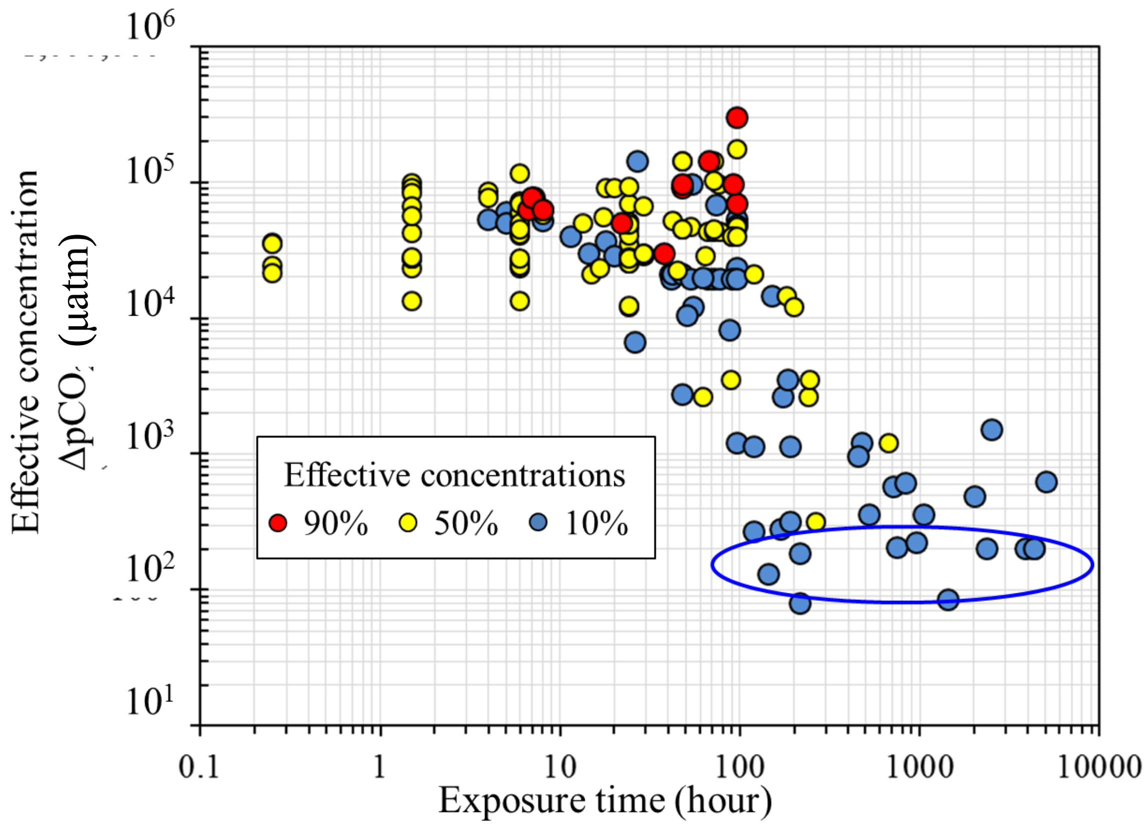
Kano et al., 2010. Model prediction on the rise of pCO_2 in uniform flows by leakage of CO_2 purposefully stored under the seabed. International J. Greenhouse Gas Control 3, 617-625.

Output: CO_2 concentration gradient in the seawater column





Example of determination of threshold for ecological impact



Ecological CO_2 impact estimated from a biological impact database

Potential impacted area

Seawater CO_2 system

As CO_2 dissolves in seawater,

$$CO_2 + H_2O \Leftrightarrow H_2CO_3 \Leftrightarrow HCO_3^- + H^+ \Leftrightarrow CO_3^{2-} + 2H^+$$

(CO_2aq)

Thus, to increase concentration of

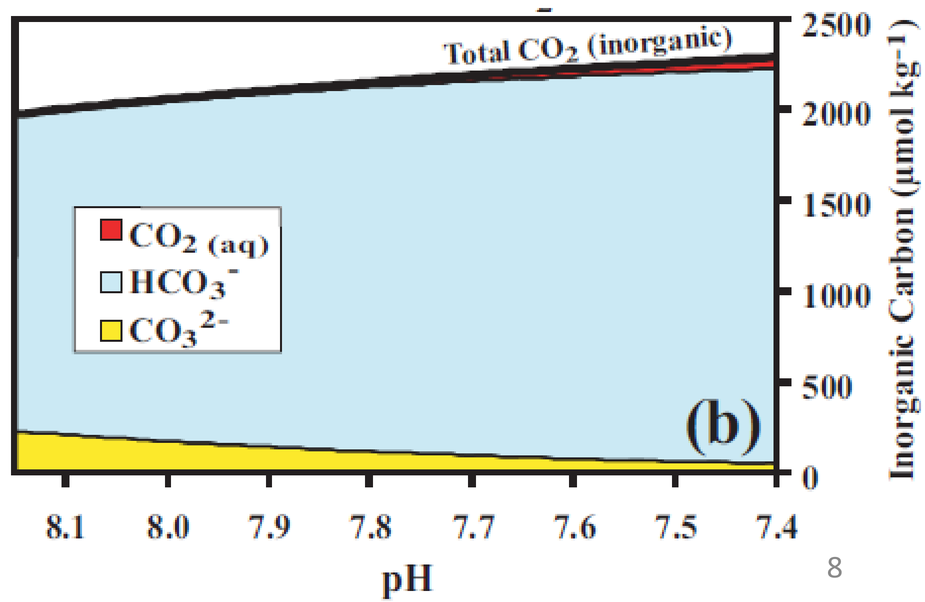
carbonic acid (H_2CO_3) ⇨ <u>*p*CO_2 increase</u>

proton (H^+) ⇨ <u>pH decrease, acidification</u>

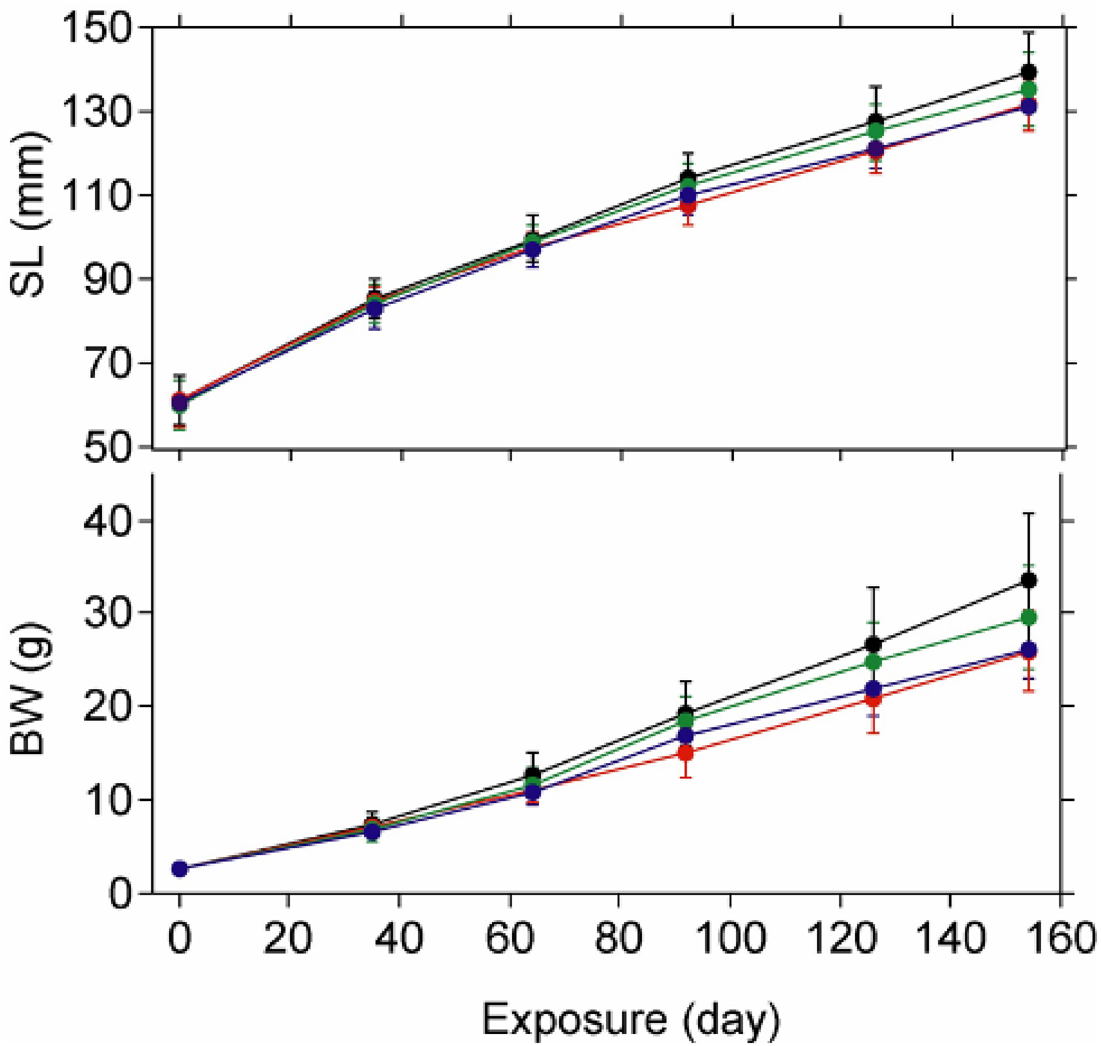
bicarbonate ion(HCO_3^-)

while decrease concentration of

carbonate ion(CO_3^{2-})



CO_2 Effects on fish growth



Kita et al. unpublished

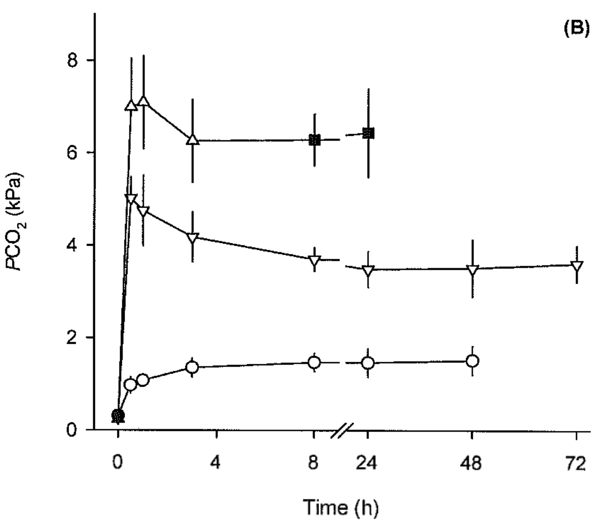
●: pCO_2=400μatm (control)
●: pCO_2=4,000μatm
●: pCO_2=7,000μatm
●: pCO_2=12,000μatm
Bars represent SD.

Growth of young *Sillago japonica* under sublethal CO_2 concentration.

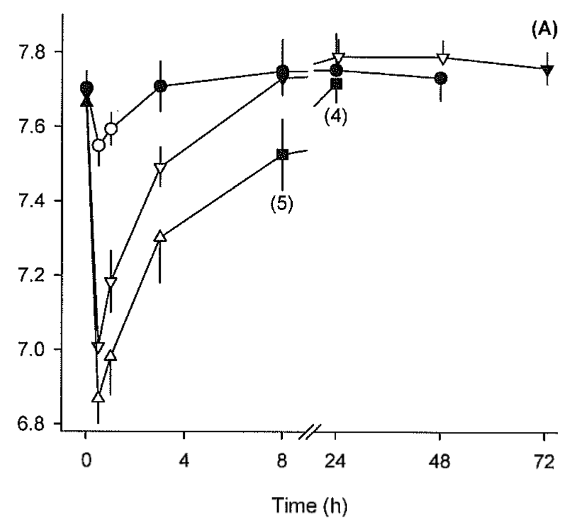
CO_2 effects on fish physiology

Hayashi et al. 2004.

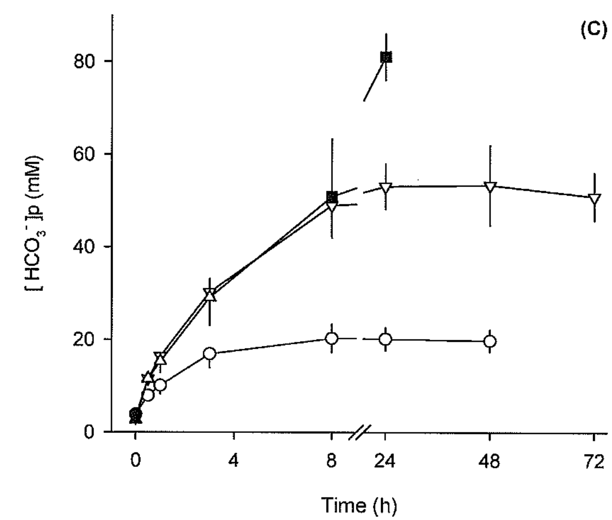
Arterial $p$$CO_2$



Arterial pH



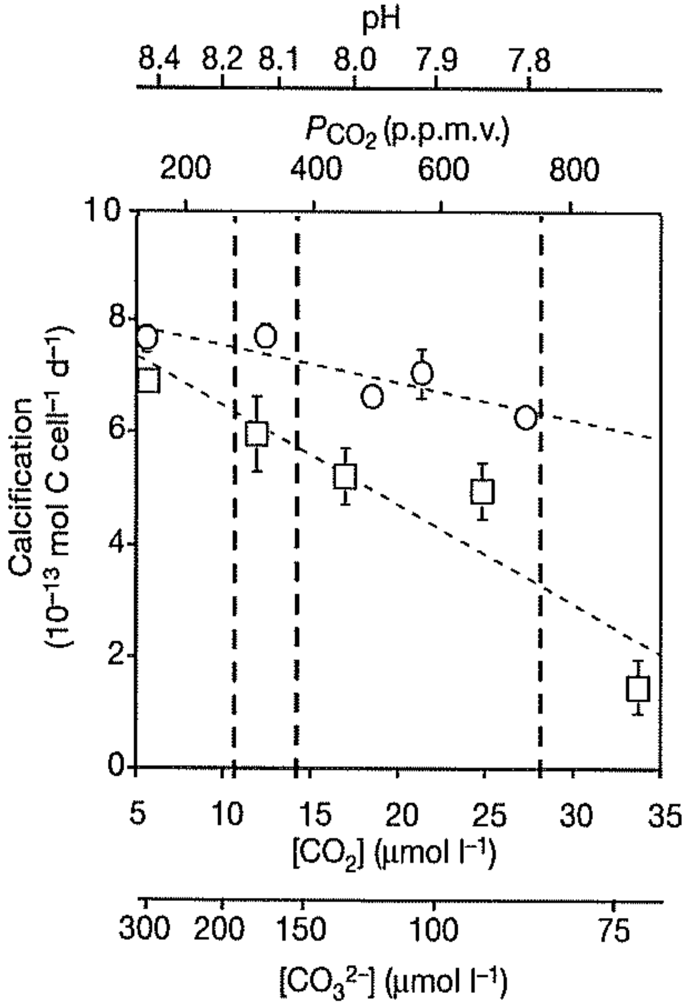
Plasma bicarbonate

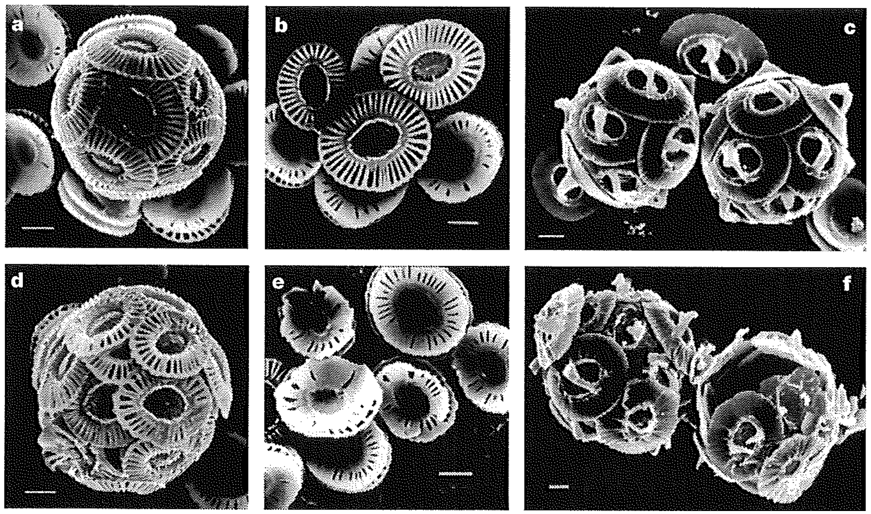


Acid-base change of Japanese flounder during CO_2 exposure of 10,000matm (●), 30,000matm (▼) and 50,000matm (▲).

Effects of high-CO_2 on coccolithophores, phytoplankton with calcite plates

Riebesell et al., 2000



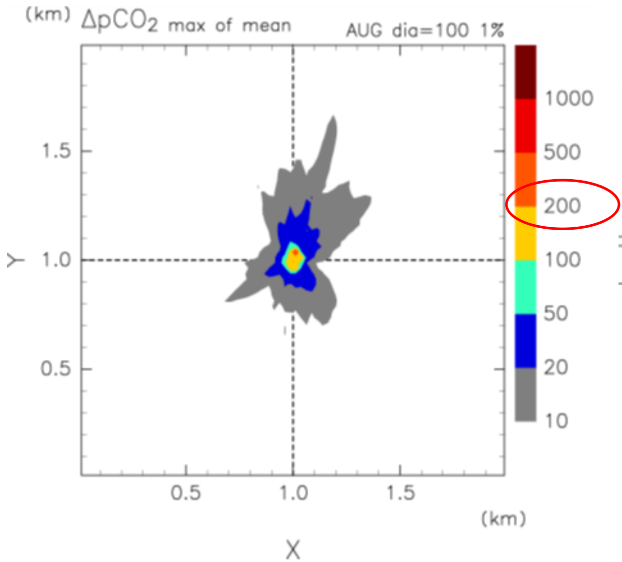


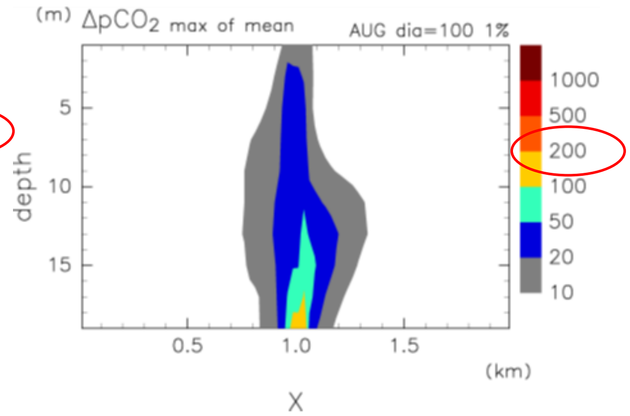
Calcification of the coccolithophorids *Emiliania huxleyi* (○) and *Gephyrocapsa oceanica* (□) as a function of CO_2 concentration.

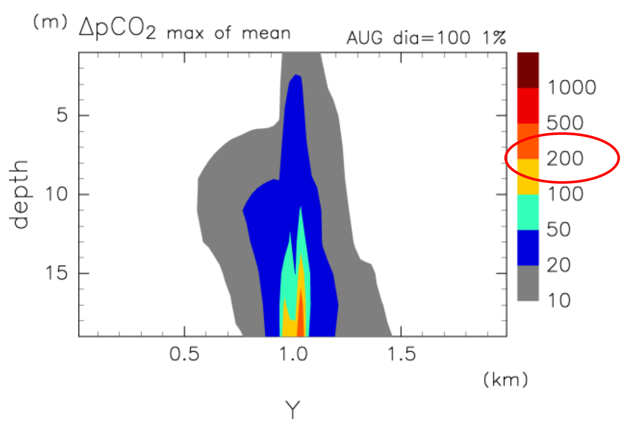
Effects of high-CO_2 on marine organisms

Organisms	pCO_2	Effect
Calcifiers • Molluscs • Echinoderms • Corals • Coccolithophores	$\Delta 200 \mu atm <$	Calcification decrease
Non-calcifiers • Fish • Molluscs • Copepods	$\Delta 2{,}000 \mu atm <$	Physiological disturbance

Example of estimation of ecological impacted area



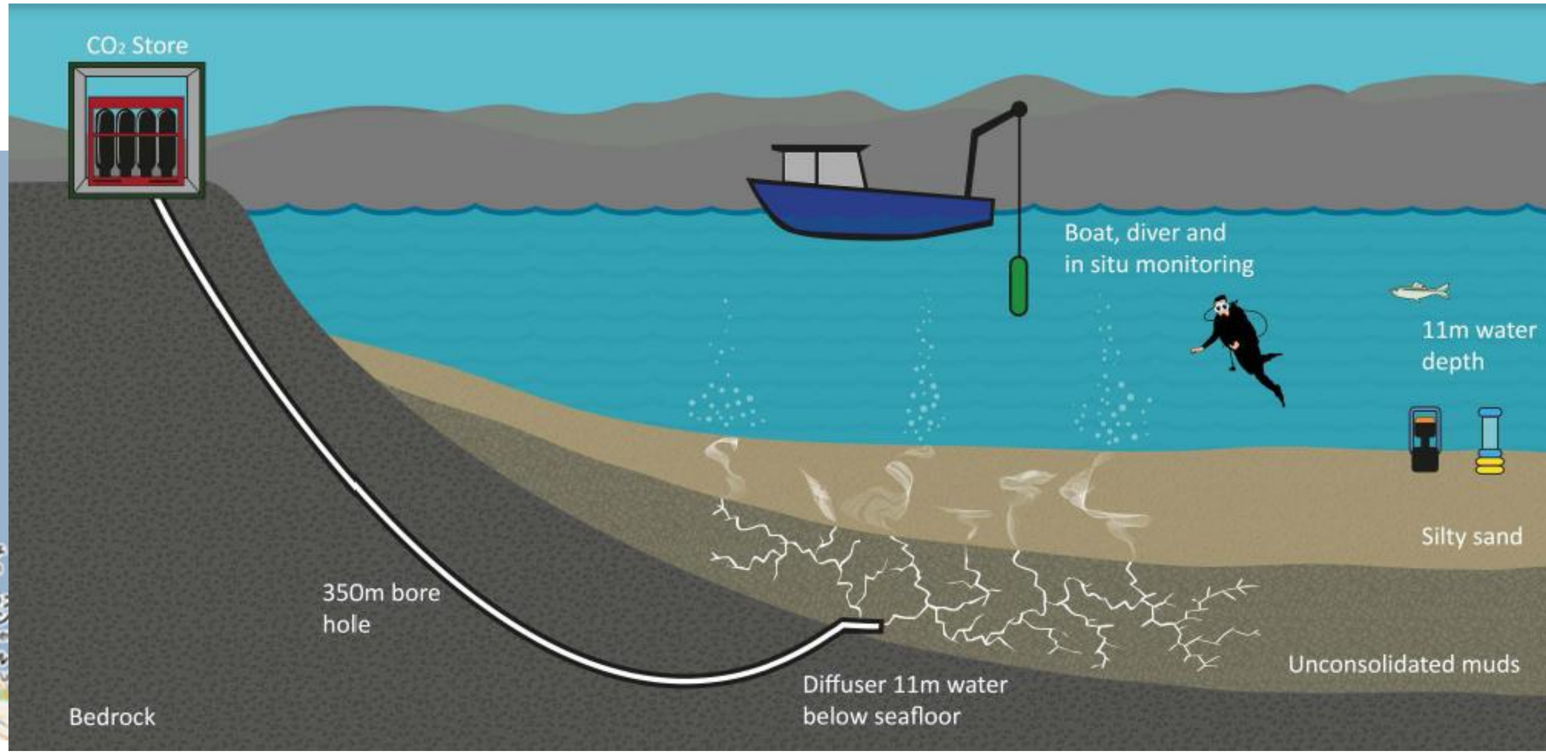




- Ecological impacted area would be negligibly small even under the extreme leakage scenario

Collaboration with QICS project UK

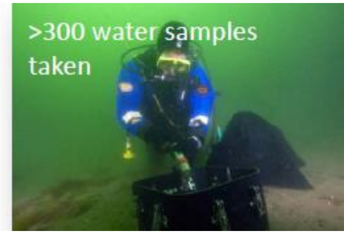
Quantifying and Monitoring Potential Ecosystem Impacts of Geological Carbon Storage



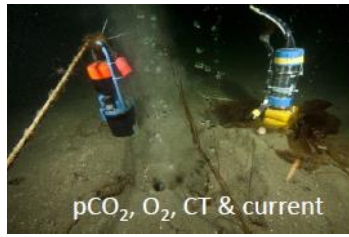
- If CO_2 leaked into the living marine environment what are the likely ecological impacts, would they be significant?
- What are the best tools, techniques and strategies for the detection and monitoring of leaks – or assurance that leakage is not happening, in the vicinity of the sea floor.

Summary from QICS

Diving surveys & sampling



In situ sensors & mesurements



Ship-board mesurements

- The biological impact was minimal and the recovery was rapid.
- Multiple monitoring methodologies in a staged approach are recommended.
- Impacts of CCS leakage should not be seen as an impediment to the development of full scale CCS.

Outputs from QICS

www.qics.co.uk

nature climate change **4, 1011-1016 (2014)**

Blackford et al.

Detection and impacts of leakage from sub-seafloor deep geological carbon dioxide storage

INTERNATIONAL JOURNAL OF Greenhouse Gas Control

21 research papers

Special issue: CCS and the Marine Environment

Volume 38, July 2015

Concluding Remarks

Environment impact assessment for offshore CCS:

- ✓ Important for public acceptance
- ✓ Necessitates a wider dialogue between scientists, policymakers, the public and civil society groups
- ✓ International collaboration is highly desirable