Biogeochemical properties of shallow-water CO_2 seeps on Himeshima Island and Showa Iwojima Island, Japan

(Fujii *et al.*, 2025, Prog. Earth and Planet. Sci., 12, 101)

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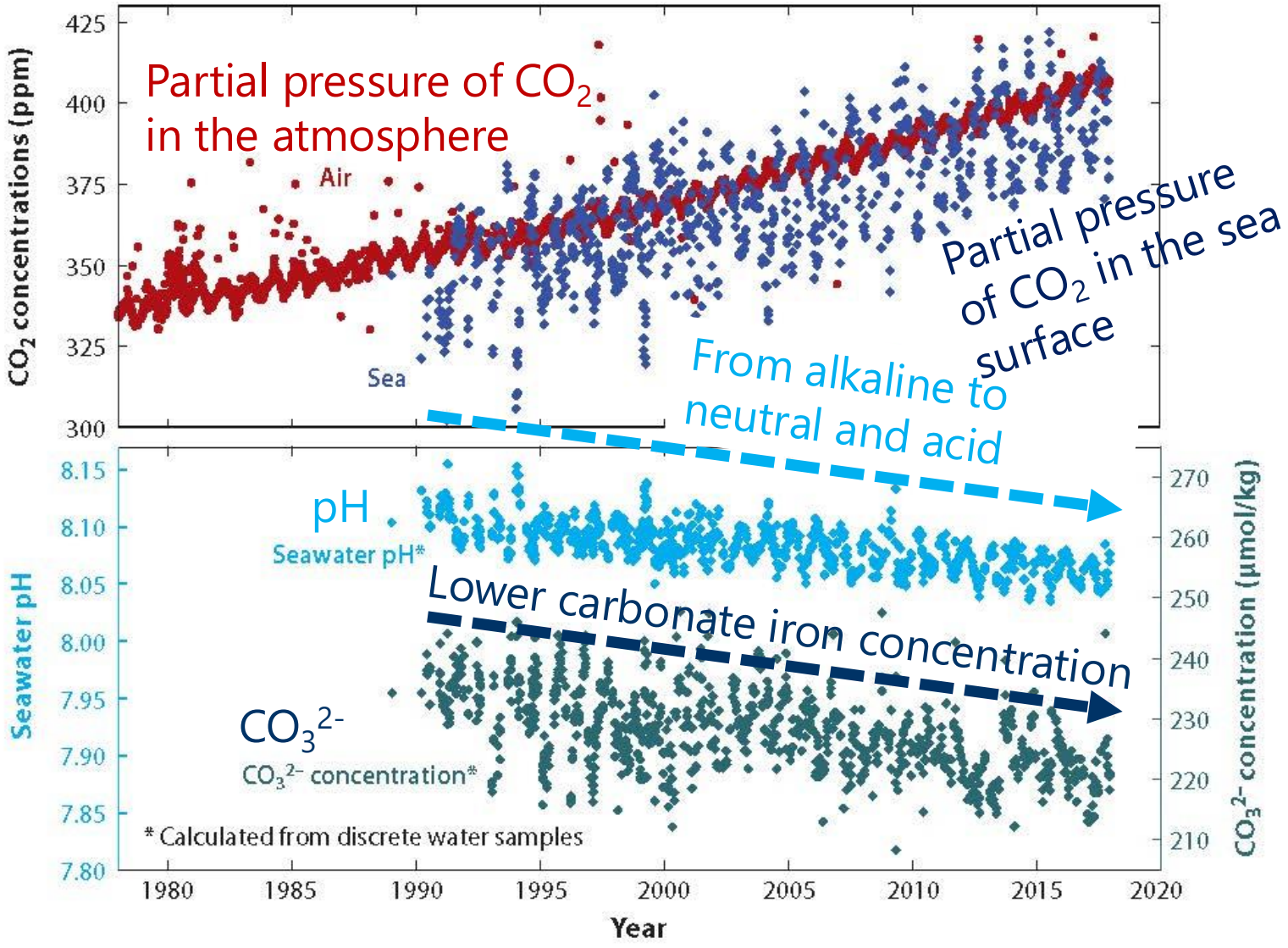
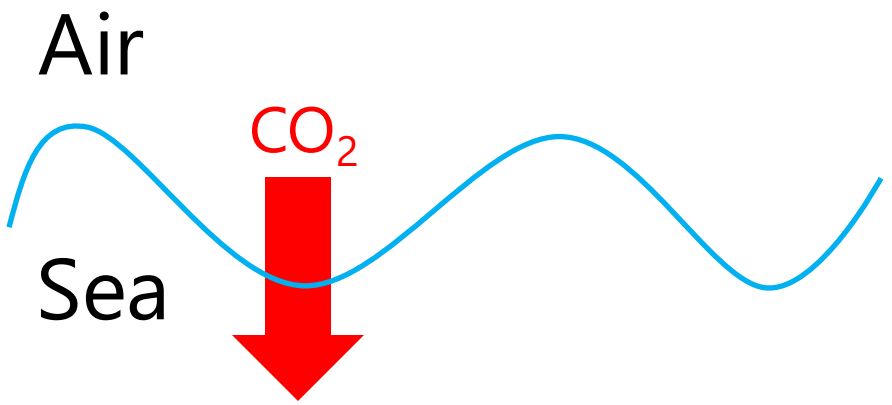
- Mishima Village, Kagoshima, Japan

Ocean acidification —Another CO_2 issue—



(Modified from Doney *et al.* (2020, Annu. Rev. Environ. Resour.))



$CO_2 + H_2O \rightarrow H^+ + HCO_3^-$

$H^+ + CO_3^{2-} \rightarrow HCO_3^-$
(Buffering effect of seawater)

Main indicators of ocean acidification

- $pH = -\log[H^+]$
- Saturation state of aragonite ($CaCO_3$)

$$\Omega_{arag} = \frac{[Ca^{2+}]\,[CO_3^{2-}]}{K_{sp}}$$

Who suffers from ocean acidification?









- Marine organisms of which shells and bodies are made of calcium carbonate ($CaCO_3$) and/or magnesium carbonate ($MgCO_3$), such as corals, shellfish, shrimps, crabs and sea urchins

- Humans and the societies that rely on these marine organisms, such as via fisheries and marine tourisms

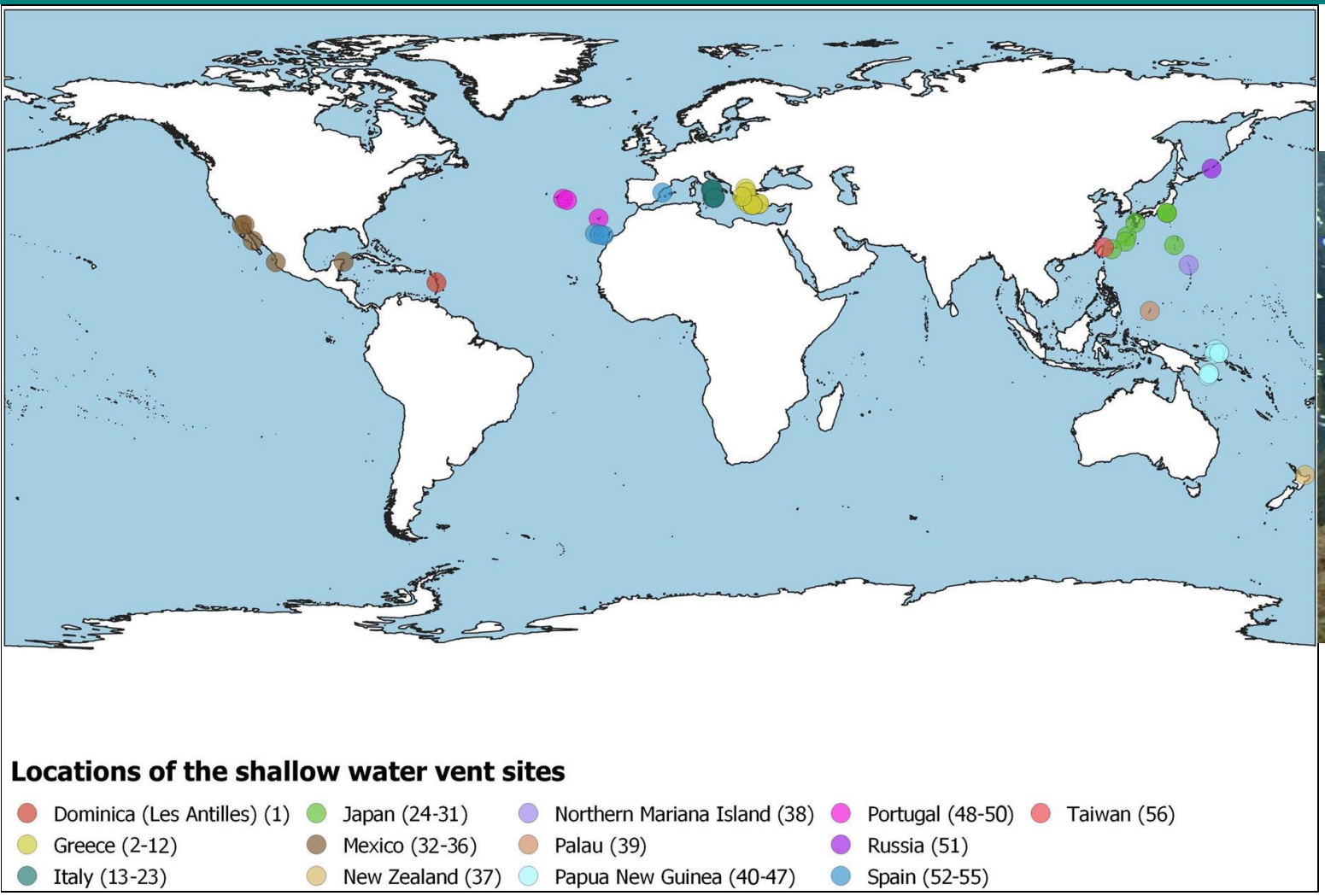
The ways to project the impacts of ocean acidification on marine organisms in the future

1. Marine ecosystem modeling
→ Models can only incorporate known findings

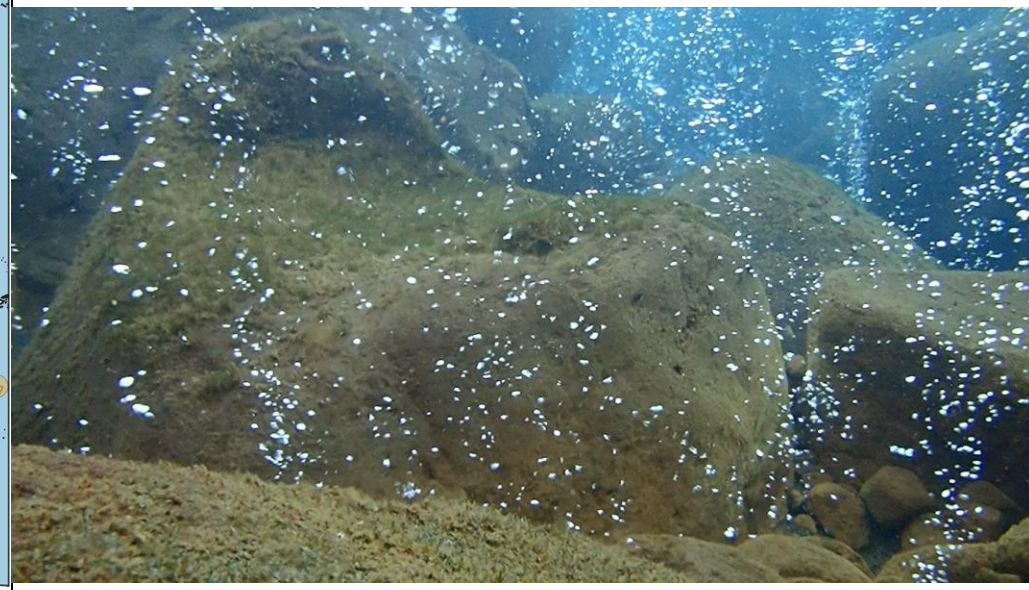
2. Investigate biological responses through tank experiments in seawater with elevated CO_2 and lower pH levels
→ Only single or a few marine organisms for which tank experiments have been established can be reared. The impacts of complex interspecies relationships and food chains remain unknown.

3. Investigate biological responses in the real ocean with naturally high CO_2 and low pH levels, *i.e.*, CO_2 seeps

Shallow-water CO_2 seeps as natural analogues of the future ocean



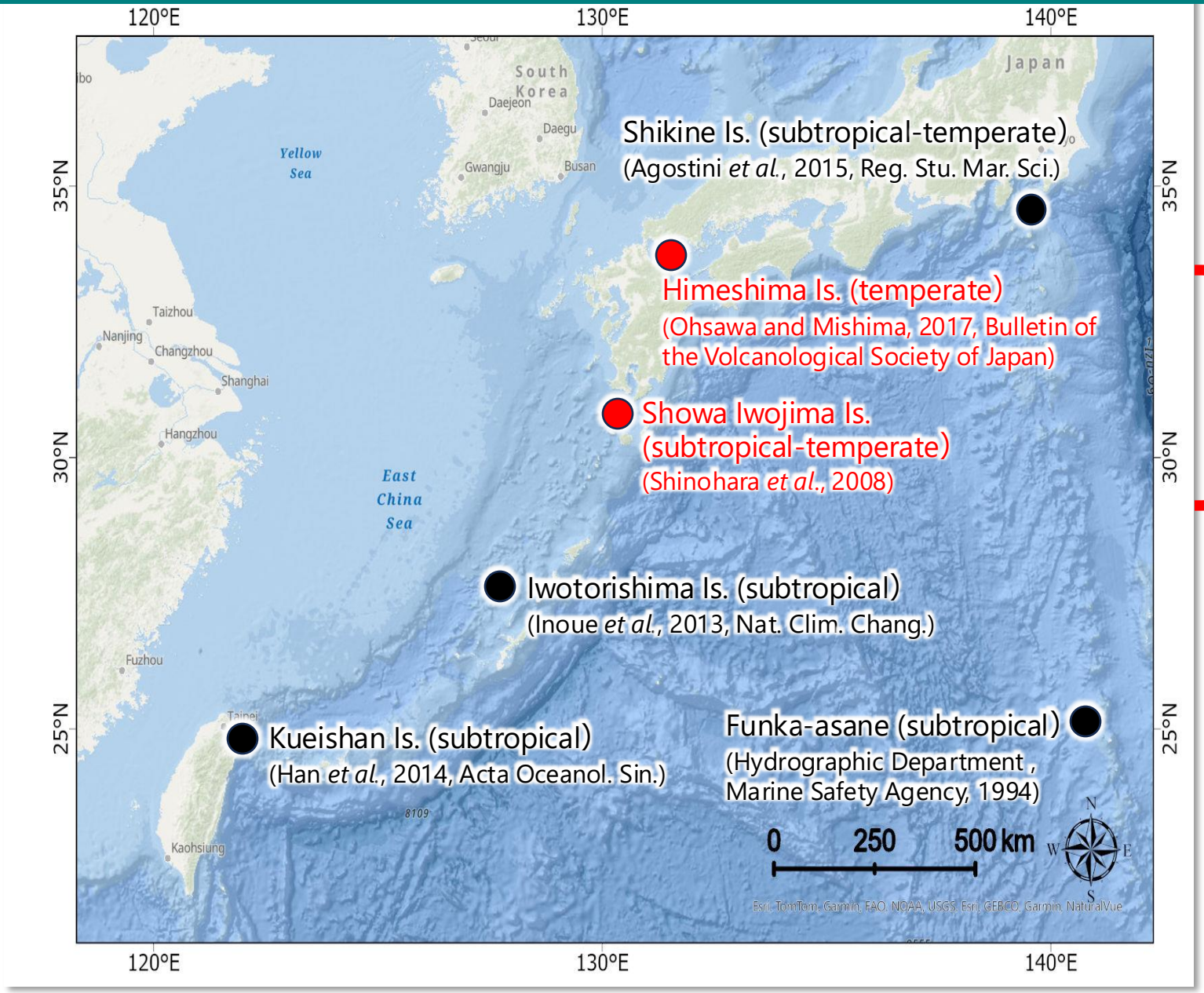
(Aiuppa *et al.*, 2020, Biogeochem.)



CO_2 seep
on Showa Iwojima Island,
Kagoshima, Japan

- Anticipate the future ocean environment in which ocean acidification has progressed.
- Important to study the distribution, function, and biodiversity of marine ecosystems at shallow-water CO_2 seeps to project the impacts of ocean acidification on marine ecosystems in the future.

Shallow-water CO_2 seeps around Japan and Taiwan (found so far)



(Map drawn by Jen-Han Yang (National Sun Yat-sen University))

Both CO_2 seeps are located inside the Japan Geoparks

- Most CO_2 seeps have been studied from the perspectives of volcanology and geochemistry.
- Only the CO_2 seeps on Iwotorishima and Shikine Islands have been studied from the perspective of ocean acidification.

Experimental design

Both Himeshima and Showa Iwojima Islands

- Short-term monitoring of water depth, temperature, salinity and pH
- Water sample collection and analysis to measure salinity, dissolved inorganic carbon and total alkalinity.

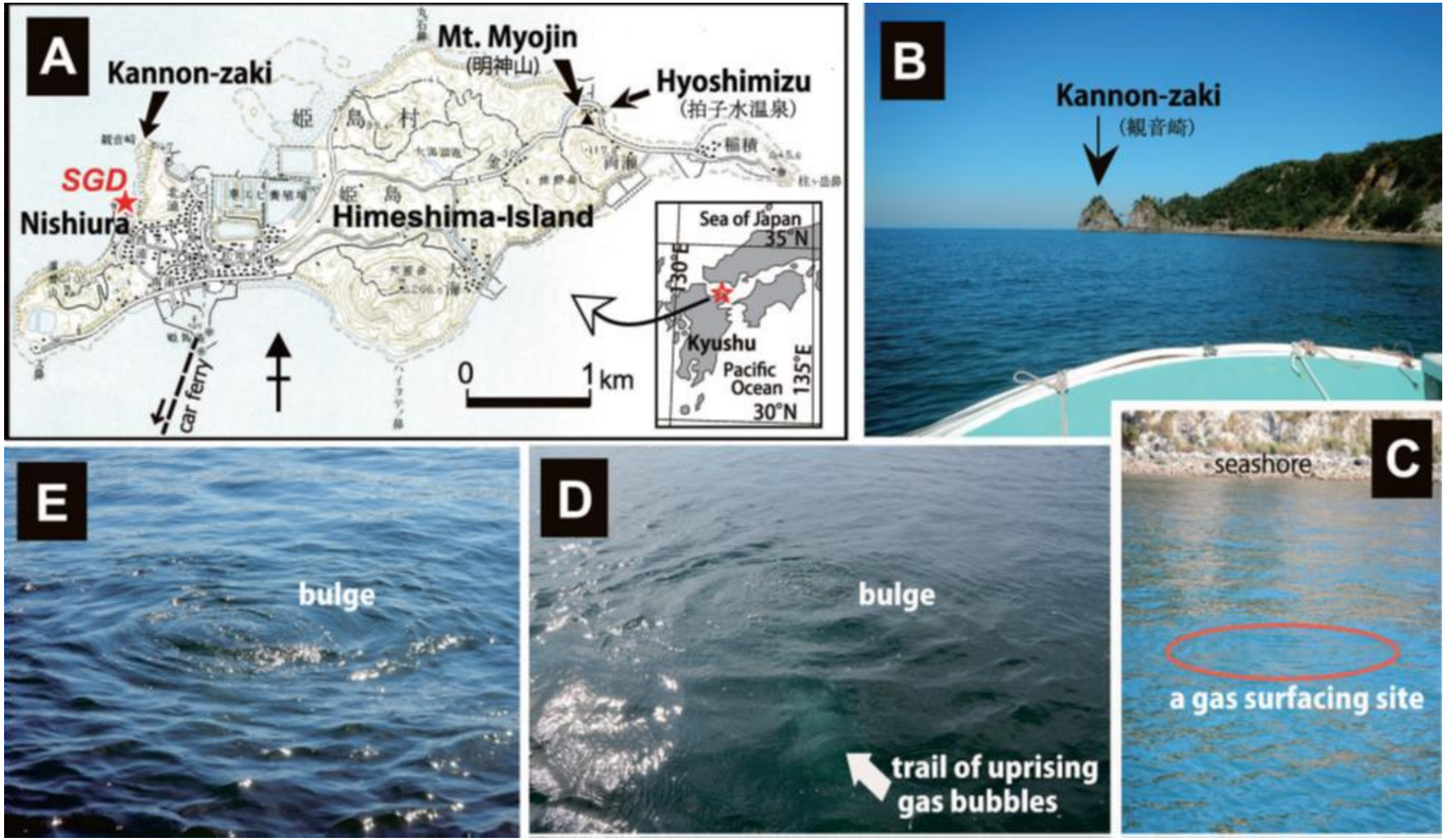
Himeshima Island

- Long-term monitoring of water depth, temperature, salinity and pH
- Seabed was photographed along a 100 m transect between CO_2 seep and non-CO_2 seep areas to identify benthic communities.

Showa Iwojima Island

- 50 cm × 50 cm frame was placed on the seabed at CO_2 seep, non-CO_2 seep, and transition areas, and photographs were taken above the frame to identify benthic communities.

Shallow-water CO_2 seep on Himeshima Island

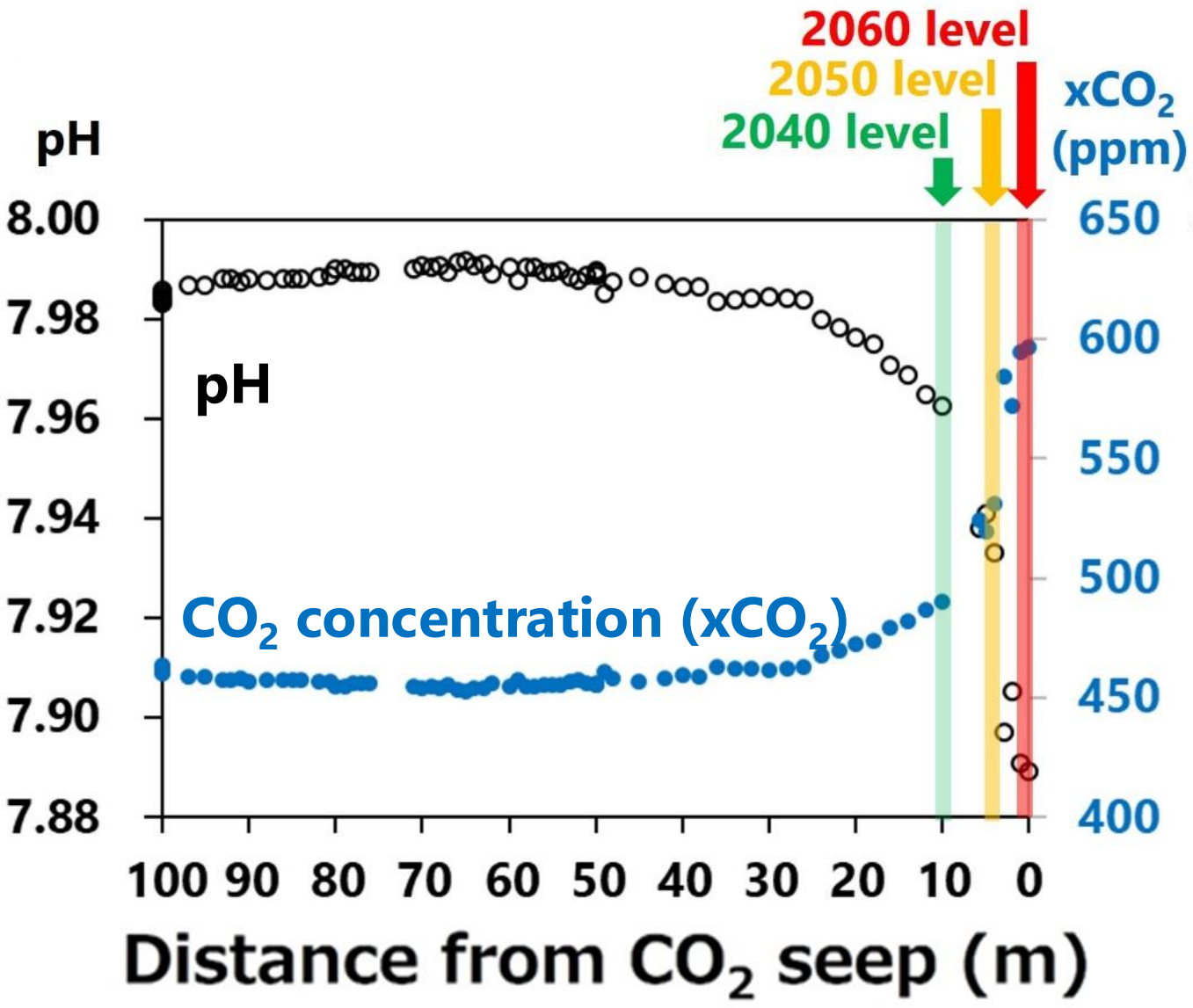


(Ohsawa and Mishima, 2017, Bulletin of the Volcanological Society of Japan)

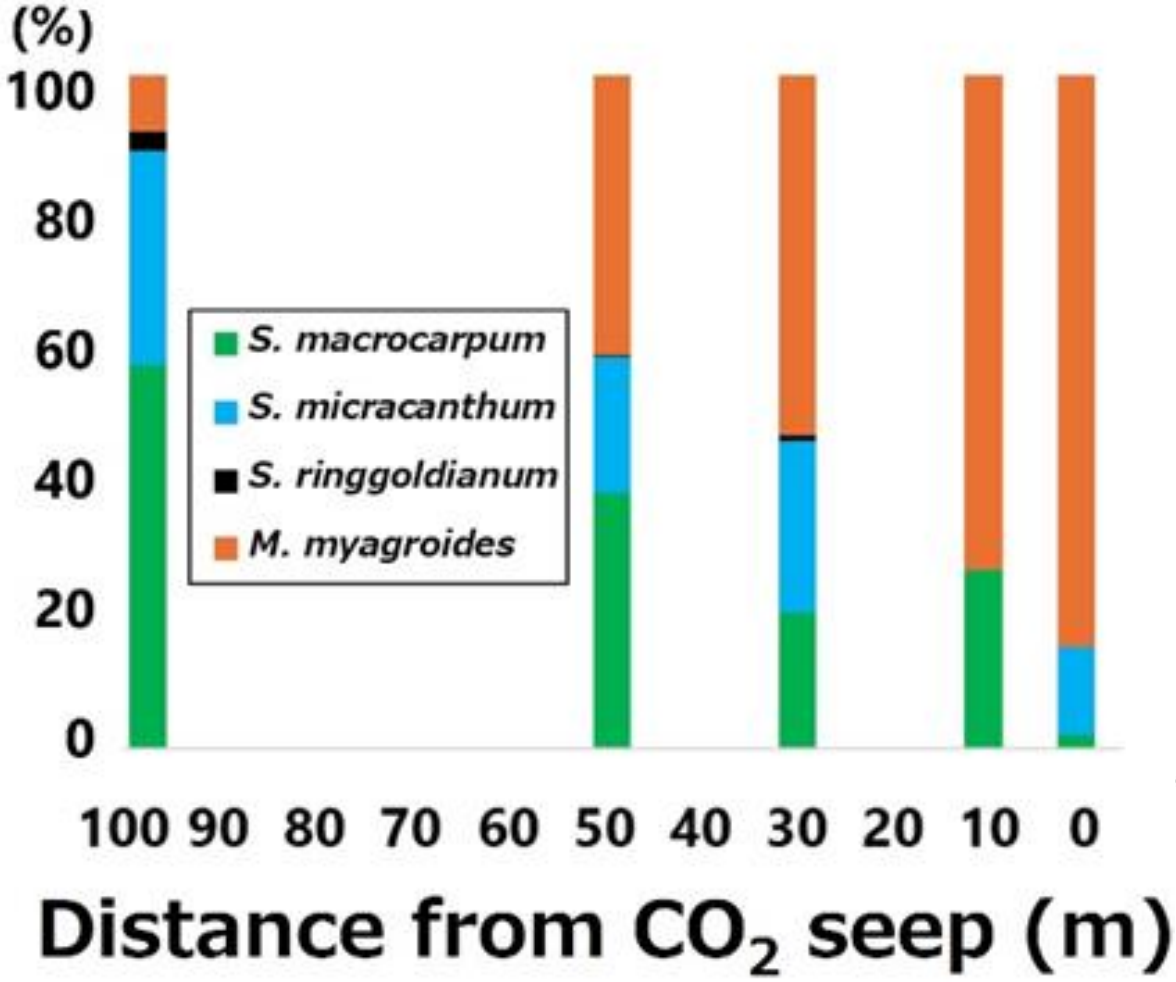
Shallow-water CO_2 seeps on Himeshima Island, Japan

Fujii *et al.* (2025, Prog. Earth Planet. Sci.)

(IPCC RCP 8.5 scenario)



Composition ratio (%) of coverage of Sargassaceae (large seaweed) family



Shallow-water CO_2 seeps on Showa Iwojima Island, Japan

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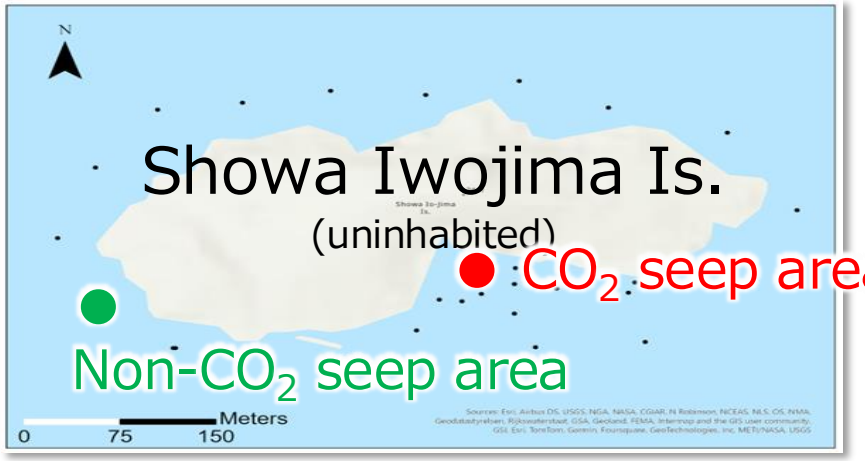
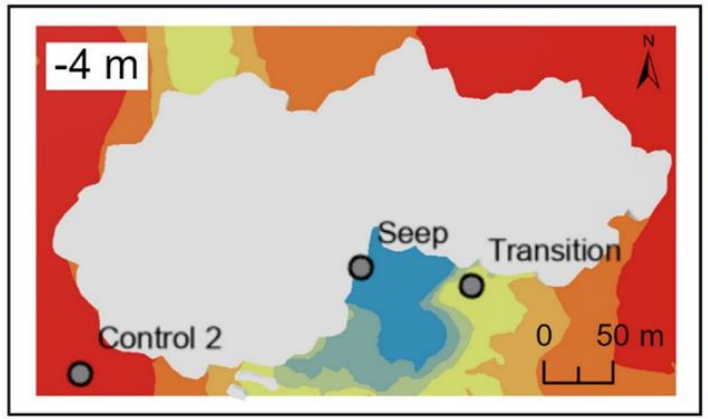


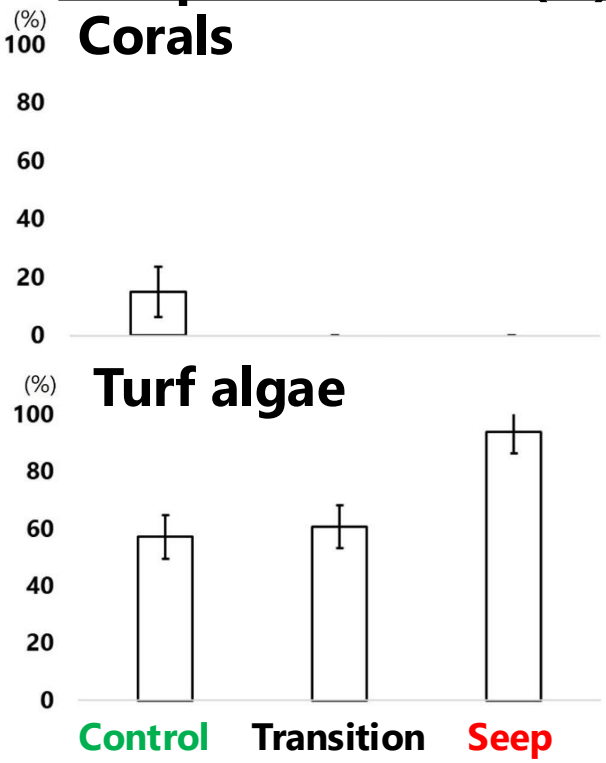


8.1 – 8.2
8.0 – 8.1
7.9 – 8.0 (CO_2 2040-2060 level)
7.8 – 7.9 (CO_2 2060-2090 level)
7.7 – 7.8 (CO_2 2090-2100 level)
7.6 – 7.7
< 7.6

Non-CO_2 seep area

- Typical subtropical corals and coral reef fish dominant

Composition ratio (%)



CO_2 seep area

- No corals and coral reef fish
- Turf algae dominant

Summary

First study to investigate CO_2 seeps on Himeshima and Showa Iwojima Islands, Japan, from the perspective of ocean acidification.

At the CO_2 seep areas, we found:

- Significantly high CO_2 concentrations, and low pH values
- The pH values close to or lower than those anticipated to reach 2100 unless anthropogenic CO_2 emissions are reduced sufficiently
- Clear shift of dominant species and less marine biodiversity, suggesting significant impacts of ocean acidification on marine ecosystems in the future

Located within the Japan Geoparks, the shallow-water CO_2 seeps can be positioned as:

- Subjects of studying biological responses to future climate change
- Fields of study tour and ecotourism from the perspective of local geoparks

Intercomparison of CO_2 seeps with different marine environments is ongoing to elucidate compound impacts of ocean warming and acidification on marine ecosystems in the future.