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Initial success in estimating effects of rising sea surface temperature and ocean acidification on corals in the seas around Japan

Points gleaned from the study:

- Regional ranges of coral habitats in the seas around Japan will be largely reduced in future due to global warming and ocean acidification.
- It is critical to take measures to control CO_2 emissions to maintain healthy coral communities.

Summary of the study's results

Researchers from Hokkaido University, the National Institute for Environmental Studies (NIES), the Swiss Federal Institute of Technology Zurich (ETH), and University of Bern, using data of sea surface temperature and aragonite saturation[1)] projected from four coupled global carbon cycle-climate models, estimate that the habitat suitable for tropical/subtropical corals in the seas around Japan (hereinafter referred to as the "regional ranges of coral habitats") may be largely reduced in future due to the effects of future global warming and ocean acidification[2)] (We used a scenario of a diversified society (SRES A2[3)]), which assumes business-as usual emissions over the 21st century).

This is the first study in the world to estimate the effects of both rising sea surface temperature and ocean acidification on corals and to prove that it is indispensable to take measures to reduce CO_2 emissions to maintain healthy coral habitats.

Summary of the paper is published as:

Title: Ocean acidification limits temperature-induced poleward expansion of coral habitats around Japan

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Summary of the study results

(Introduction)

An increase in atmospheric CO_2 due to human-induced global warming causes sea surface temperatures to rise and greater CO_2 absorption by the seawater that leads to "ocean acidification". In the Aichi Target adopted at the 10th Conference of the Parties to the Convention on Biological Diversity (COP10), it was reported that coral reefs are frail habitats against rising sea surface temperatures and ocean acidification, and it was agreed that maintaining safe coral habitats was critical. In recent years, rapid expansion and distribution of coral habitats at high latitudes has been reported due to rising sea surface temperatures; therefore, it is estimated that distribution of coral habitats will continue to expand to higher latitudes. On the other hand, coral bleaching is expected to occur more frequently in tropical/subtropical areas, at lower latitudes; again this is due to rising sea surface temperatures. In the summer of 1998, coral bleaching was observed at a global scale never before reported.

However, compared to the effects of rising sea surface temperatures, the effects of ocean acidification have rarely been estimated. While coral habitats expand to higher latitudes, lowered aragonite saturation caused by ocean acidification expands from a low sea surface temperature area at high latitudes, and formation of coral skeletons is apt to be inhibited in oceanic areas with lower aragonite saturation.

In Japan, which is an island stretching from low latitudes to high latitudes, coral communities expand from subtropical to temperate zones and are profoundly impacted by both rising sea surface temperatures and ocean acidification. These conditions can be used to establish model cases to evaluate the effects of an increase in CO_2 emissions on coral habitats. Using sea surface temperature and aragonite saturation data projected from four coupled global carbon cycle-climate models and simple indices related to the northern limit of coral reefs, we estimated the potential expansion of regional ranges of coral habitats around Japan due to rising sea surface temperatures（inducing poleward expansion and coral bleaching）and lowered aragonite saturation caused by ocean acidification (inhibiting coral calcification), with a scenario of a diversified society (SRES A2).

(Method)

Indices of regional ranges for each of tropical/subtropical and temperate coral communities were set up based upon the present range or past study results. To establish indices for tropical/subtropical coral communities, we used 18°C for the sea surface temperature and 3 for the surface aragonite saturation value, during the coldest months, at Tanegashima Island of Kagoshima Prefecture, which is currently the northern limit of coral reefs dominated by coral communities located in the Ryukyu Islands.

Furthermore, regarding indices for temperate coral communities, we used 10˚C for the observed sea surface temperature during the coldest months and 2.3 for the surface aragonite saturation value at Sadogashima Island of Niigata Prefecture, where the current northern limit of coral occurrence was observed. We estimated a potential regional ranges of coral habitats, using these indices and data of sea surface temperature and aragonite saturation, which were projected from experiments under the 20^{th} century condition and prediction experiments conducted based upon a scenario of a diversified society (SRES A2), using four coupled global carbon cycle-climate models[4)].

(Results)

We estimate that the speed of the expansion of regional ranges of coral habitats to lower latitude areas due to ocean acidification (Fig. 1(b)) is much faster than the speed to higher latitude areas due to rising sea surface temperature caused by global warming (Fig. 1(a)) and poleward range expansion of coral habitats to the north due to rising sea surface temperature is inhibited by lowered aragonite saturation caused by ocean acidification. Moreover, it is estimated that oceanic areas where coral bleaching is caused by rising sea surface temperature will be shifted to higher latitude areas during the latter half of this century. More specifically, regional ranges of coral habitats in the seas around Japan are largely reduced in the future because low aragonite saturation areas caused by ocean acidification and coral bleaching areas due to rising sea surface temperature are expanded to lower and higher latitude areas, respectively. Therefore, it is estimated the seas around Japan under the scenario of a diversified society will become an extremely harsh environment to coral habitats in the future (Fig. 2).

(a) Poleward shifts of the indices for the northern limit (water temperature) of coral communities due to global warming

(b) Equatorward shifts of the indices for the northern limit (aragonite saturation) of coral communities due to ocean acidification

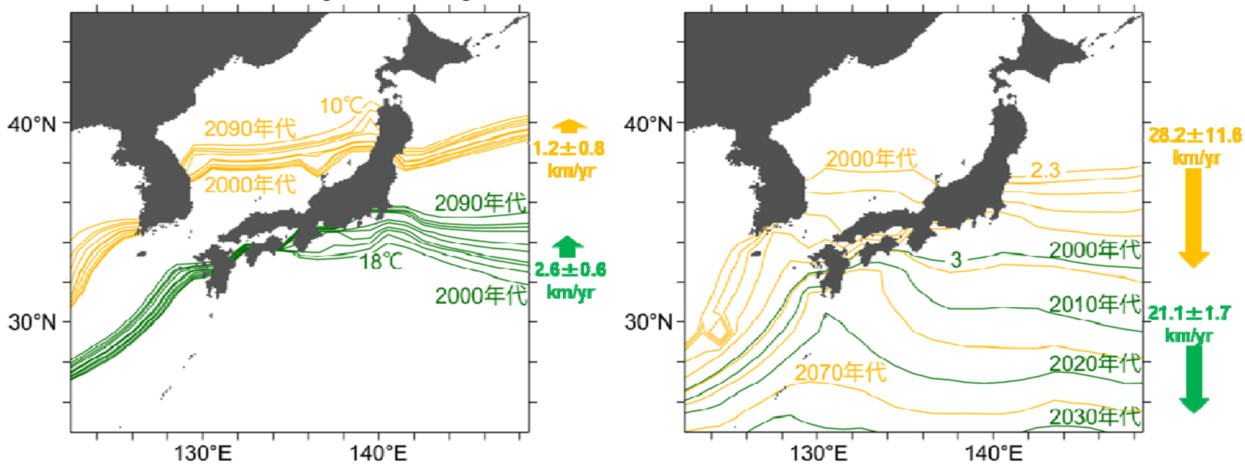

Fig. 1. Projected shifts of regional ranges of coral habitats based upon the indices for coral ranges from the present to the future. The green isothermal lines denote the northern limit of the tropical/subtropical coral communities and the orange isothermal lines denote the northern limit of temperate coral communities.

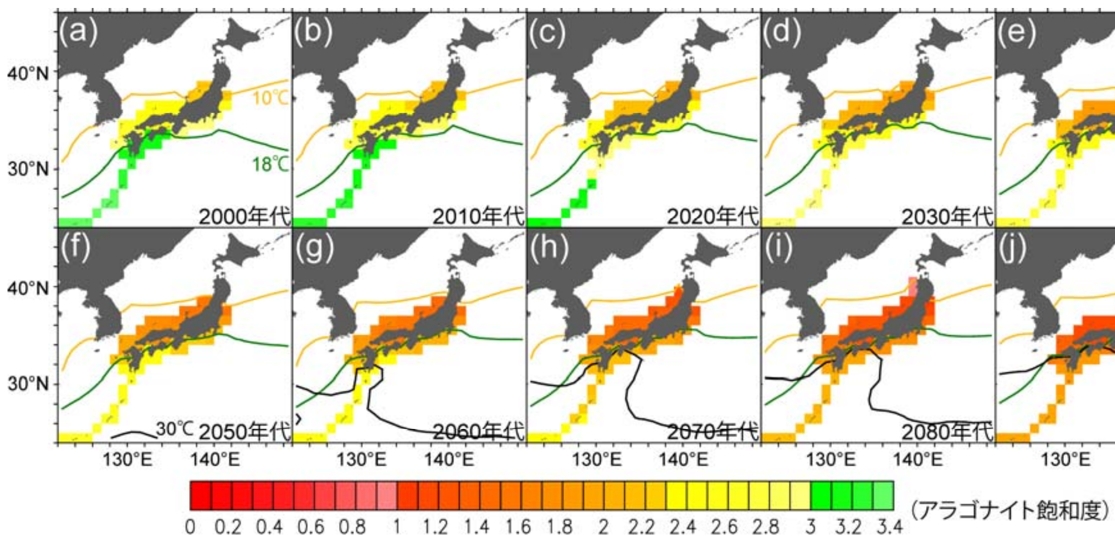

Fig. 2. Projected 10-yr mean northern limit of regional ranges of coral habitats from the present to the future. The

isothermal lines in green and orange denote the northern limit of the tropical/subtropical coral communities and the temperate coral communities due to rising sea surface temperature. The isothermal line in black denotes the northern limit of coral bleaching occurrence due to rising sea surface temperature. The color of oceanic areas denotes the value of aragonite saturation.

(Conclusions)

This is the first study to estimate that the effect of ocean acidification on coral communities is larger than that of rising sea surface temperature under a scenario of a diversified society (SRES A2), which is one of CO_2 emission scenarios; consequently, it is indispensible when seeking to reduce CO_2 emissions to maintain a healthy coral habitat.

In this study, the indices for the potential regional ranges of coral habitats were estimated from the present ranges, but the effects of climate change, especially ocean acidification on living organisms, still remain obscure and it is necessary to clarify mechanisms of acclimation and adaptation.

In future, it is necessary to promote researches while considering differences of estimated results from CO_2 emissions scenarios and acclimation and adaptation of coral habitats and propose the maximum limit of CO_2 emissions taking into account both global warming and ocean acidification.

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【Glossary】

1) Aragonite saturation: Most of coral skeletons are formed by aragonite, crystal forms of calcium carbonate, which is relatively soluble. At present, coral communities are located in oceanic areas where values of aragonite saturation are large (approximately larger than 3), but it is known if the aragonite saturation is lowered by absorbed CO_2 in the oceans, calcification to form skeletons is diminished and inhibited. According to chemical equilibrium, aragonite is dissolved if aragonite saturation becomes less than 1.

2) Climate models: are used to project future climate by calculating parameters of atmospheres and oceans. This is different from weather models that predict weather on a specific day.

3) SRES: Special Report on Emission Scenarios

[A2 Scenario: This scenario is for a society with relatively large CO_2 emissions that assumes economic development without changing the frameworks of the present society or economy radically]

4) Four coupled global carbon cycle-climate models: IPSL (IPSL-CM4-LOOP model), MPIM (Max Planck Institute for Mathematics), NCAR CSM1.4 (NCAR CSM1.4-carbon climate model), and NCAR CCSM3 (NCAR CCSM3 Biogeochemical Elemental Cycling Model)

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