沖縄の造礁サンゴの海洋酸性化と海洋温暖化に対する反応の種間および種内変異

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Abstract

Anthropogenic emission of CO_2 into the atmosphere has been increasing exponentially, causing ocean acidification (OA) and ocean warming (OW). The "business-as-usual" emission scenario predicts that the atmospheric concentration of CO_2 may exceed 1,000 μatm and seawater temperature may increase by up to 3 °C by the end of the 21st century. OA and OW may affect the growth and survival of reef corals. OA increasingly reduces the calcification rate of the corals with the increasing pCO_2 of the seawater, and some coral species are extremely sensitive to small changes in pCO_2 of the seawater. OW has already affected the corals and is also predicted to increasingly affect the corals in near future. OW affects corals by decreased the calcification rate, and when the heat-stress is severe, coral bleaching (loss of their endosymbionts) occurs, and mass-mortality of the corals may occur after bleaching. OW causes coral bleaching by damaging endosymbionts' photosynthetic apparatus. Responses of the corals to OW may be more severe when simultaneously exposed to OA (OA+OW). The responses of the corals to OA+OW may be additive, synergistic, or antagonistic. In this dissertation, I conducted aquarium experiments to reveal the response of corals to OA, OW, and OA+OW.

First, I investigated the effect of OA on the calcification of 5 branching and 1 massive coral species by setting pCO_2 of the seawater from those in the pre-industrial era to that of this century (300 μatm –1200 μatm) (Chapter II). The results showed that the calcification rates of all the coral species decreased with increasing seawater pCO_2. However, the patterns of responses to OA were different among species. The difference among the species can be attributed to variations in the biological properties of corals, such as the calcification rate.

Second, I evaluated the effect of OA (pCO_2 ~650 μatm) on the calcification of primary polyps derived from the gametes of *Acropora digitifera* (Chapter III). The results showed that the calcification of the primary polyps decreased significantly at pCO_2 higher than the ambient, which was expected to be reached within this century, suggesting that the near-future OA would decrease the calcification of primary polyps. Third, I separately examined the effects of OW (28 and 31 °C) and OA (400 and 1,000 μatm) on the calcification of *A. digitifera* and *M. digitata* (Chapter IV). The results showed that *A. digitifera* was more OW-sensitive than *M. digitata*, whereas the former was less sensitive to OA than the latter. The sensitivity differences to OW between *A. digitifera* and *M. digitata* might be mainly related to differences in the endosymbiont species in the host corals. On the other hand, the sensitivity differences to OA between the two species might be attributable to the calcification rate and skeletal density. Fourth, I examined the effects of OA, OW, and OA+OW on the calcification and mortality of *A. digitifera* and *M. digitata* (Chapter V). An effect size test revealed that OW was the main stressor, and OA was only the second-order stressor for increasing mortality and decreasing the calcification of the host corals and decreasing the density, chlorophyll content, and photochemical efficiency (*Fv/Fm*) of the endosymbionts at OA+OW in both species. The intensity of the effects of OA+OW on these 2 coral species was additive (i.e., sum of the effects of OA alone and OW alone), probably due to OA and OW mainly affected the host corals and the endosymbionts, respectively. Fifth, I examined the intraspecific variation in the responses of the calcification and *Fv/Fm* against OA, OW, and OA+OW in *A. digitifera* (Chapter VI). Significant intraspecific variations were detected in the calcification; the calcification rate varied among colonies significantly, but *Fv/Fm* did not. *Fv/Fm* did not vary among the colonies, presumably because the endosymbiont species was the same in all the colonies. The intraspecific variation among the colonies likely to be attributed to the genetic differences of the host corals.

The results of the present dissertation suggest that, in *A. digitifera* and *M. digitata*, OA reduced the calcification rate by affecting the host corals, and OW reduced the density, chlorophyll content, *Fv/Fm* by affecting the endosymbionts. Then, the harmful effects of OW on the endosymbionts appeared to cause a reduction in the calcification and bleaching of the coral hosts. The effect of OA+OW was additive in these two coral species, presumably because OA and OW mainly acted on host corals and endosymbionts, respectively. When OA and OW occur simultaneously, as supposed in the high pCO_2 world in the future, corals may be generally affected more by OA+OW than OA alone and OW alone. OW may be the main stressor of mortality and reduced calcification, while OA may be the second-order stressor in other coral species.