Ocean Acidification and Solar UV Radiation Interact Synergistically to Reduce Algal Calcification

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The acidity of the surface oceans has already been increased by 30% due to atmospheric CO_2 rise. It would likely be increased by 120% in 2060 under the 'business-as-usual' emission scenario. Such a progress of ocean acidification has been suggested to harm marine calcifying organisms by reducing the rate of calcification of their skeletons or shells. On the otherhand, UV-B irradiance reaching the earch has been increasing due to thinned ozone layer.

Previous studies have shown that increasing atmospheric CO_2 concentration affects calcification in some planktonic and macroalgal calcifiers due to changed carbonate chemistry of seawater. However, little is known on how calcifying algae respond to solar UV radiation (UVR, 280–400 nm). UVR may act synergistically, antagonistically or independently with ocean acidification (high CO_2/low pH seawater) to affect their calcification processes. Here we show that in the absence of UVR, the calcification rates in the coccolithophore *Emiliania huxleyi* decreased under lowered pH levels (pH_{NBS} of 7.9 and 7.6; pCO_2 of 804 and 1759 ppmv) leading to thinned coccolith layers, while photosynthetic carbon fixation remained unaffected. Exposure to UVR in addition to PAR however, results in significant inhibition of both photosynthesis and calcification and these rates are further inhibited with increasing acidification. The combined effects of UVR and seawater acidification result in the inhibition of calcification rates by 96% and 99% and that of photosynthesis by 6% and 15%, at pH 7.9 and 7.6, respectively. This differential inhibition of calcification (C) and photosynthesis (P) leads to significant reduction of the C/P ratio. Seawater acidification enhances the transmission of harmful UVR by about 26% through a reduction of the coccolith layer of 32%. Our data indicate that the impact of a high CO_2/low pH ocean on *E. huxleyi* (due to reduced calcification associated with changes in the carbonate system) enhances the detrimental effects of UVR on the major pelagic calcifier.

We also cultured the articulated coralline alga *Corallina sessilis* Yendo at 380 (low) and 1000 ppmv (high) CO_2 levels while exposed the alga to solar radiation treatments with or without UVR. Presence of UVR, in contrast to PAR alone treatment, inhibited the growth, photosynthetic O_2 evolution and calcification rates by13%, 6% and 3% at the low and by 47%, 20% and 8% at the high CO_2 concentrations, respectively, reflecting an synergistic effect of CO_2 enrichment with UVR. UVR induced significant decline of pH in the CO_2-enriched cultures. The contents of key photosynthetic pigments, Chl.a and phycobiliproteins decreased, while UV-absorptivity and contents of carotenoids increased under the high pCO_2/low pH condition. Nevertheless, UV-induced inhibition on photosynthesis increased when the ratio of PIC/POC decreased under the CO_2-acidified seawater, reflecting a UV-protective role played by the calcified layer. Both UVA and UVB negatively impacted the photosynthesis and calcification, however, the inhibition caused by UVB was about 250–260% higher than by UVA. The results imply that coralline algae may suffer from more damages caused by UVB when they calcify less and less with progressing ocean acidification.

In conclusion, calcification of the calcifying algae decreased under the simulated ocean acidification conditions and further declined in the presence of UV. These results indicate that ocean acidification is not the only problem threatening the survival of calcifying algae.

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