Reef Refugia to Climate Change

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Introduction:

Climate change including global warming and ocean acidification is suspected to have profound impacts on the marine ecosystems at a global scale (IPCC 2011). Among them, coral reef ecosystem is suspected to be principally affected by the climate change (Hoegh-Guldberg et al. 2007). Number of experiment and field studies demonstrated that the increase of seawater temperature and seawater acidity induces coral bleaching and decrease of net calcification. CO_2 vent studies also revealed that high CO_2 could cause shifts in reef community structure and decrease of biological diversity (Fabricius et al. 2011, Inoue et al. 2013, Enochs et al. 2015). However, recent studies have indicated the possible existence of some reef system that could work as a refugia to the climate change (Manzello et al. 2012, Yates et al. 2014, Cacciapaglia and van Woesik 2015, Barkley et al. 2015). Here, we examined the water chemistry and reef community within an inner reef bay (Nikko bay) in Palau that show natural low pH and high temperature gradient and high coral cover community to understand the factors generating the resilience of this community. Transplantation and tank experiments using the coral *Porites cylindrica* was also conducted to evaluate the potential local adaptation to warmed and acidified environment.

Methods

Nikko Bay is a highly sheltered bay with spatially heterogeneous seawater chemistry due to the complex topography and high water residence time. We conducted a fine scale carbon chemistry measurement including pH, total alkalinity (TA), dissolved inorganic carbon (DIC), aragonite saturation (Ω_{arag}) salinity and temperature, and water quality measurement including nutrient, Chl-*a*, turbidity and dissolved oxygen (DO) within the bay. For the evaluation of the effect of pH/temperature at community level, we conducted benthic community surveys at 7 sites along the gradient of the seawater pH and temperature. Reciprocal transplantation experiment and tank experiment using the coral *Porites cylindrica* collected from different sites was performed to study the possible adaptation of the corals to high temperature and low pH condition.

Results and discussion

The seawater chemistry was spatially highly heterogenic and seawater pH within the bay ranges from 7.6 to 8.1 (average 7.8), aragonite saturation (Ω_{arag}) from 1.8 to 3.6 (2.4) and the temperature from 30 to 33°C (average 32°C). Coral density range from 38 to 82% with the average of 60%, and show the highest coverage among the benthic communities. Net calcification rate was calculated to be 22 mmol $CaCO_3$ m^{-2} d^{-1} which value was higher than the value measured out of the bay. Coral community structure differ between sites however, coral biodiversity increase with the decline of $\Omega_{arag.}$ The coral *Porites cylindrica* show the highest coverage within whole bay, which percentage account for 50% of whole coral community. There was no significant change on macroalgae, sea grass and calcareous algae density with Ω_{arag}, while turf algae density decrease with $\Omega_{arag.}$ Reciprocal transplantation and tank experiment indicated that the calcification rate of coral *P. cylindrica* collected from both out and within the bay

decrease with Ω_{arag} and temperature. However, the corals originated from the lowest pH and highest temperature site show higher resilience to the low pH and temperature compared to the corals out of the bay, suggesting acclimatization for these corals to warmed and acidified environment. We will further discuss for the mechanisms underlying this possible refuge system to the future climate change.

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