

Regional Coral Monitoring and Viability by Boat-based Observation

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There are concerns about coral decline all over the world due to global climate changes or tropical land developments, etc. To establish the current status of coral distribution, a large-area, high-efficiency coral monitoring method is required. In this study, a new coral monitoring technique is developed based on a boat observation. It can cover the survey line of more than 100 m length easily, which is difficult by the diving investigation. This technique is applied by properties of fluorescent proteins innate in hermatypic corals. It is called a boat-based fluorescent imaging LIDAR (LIght Detection And Ranging) technique, which shoot UV (Ultra Violet) pulsed laser from the boat to the seafloor, and take a frame by a gated ICCD camera in synchronization with laser. It makes possible to get only a weak coral fluorescent image by UV excitation and suppressed the sunlight background effect, since the pulse width of the laser is only less than 10 ns, and the exposure time of the gated ICCD camera is only around 100 ns. Most of live hermatypic corals have fluorescent proteins, and they show blue to green fluorescence by UV excitation. In contrast, after death of the hermatypic corals, fluorescent proteins are degraded, and algae attached dead coral skeleton wouldn't show blue to green fluorescent light. Therefore, in this observation technique, existence of corals can be judged by the image, and the viability of corals can be judged by the contrast of fluorescent image. This coral observation technique can ensure the long survey line along with the boat track, by simultaneous observation with DGPS position observation, SONAR depth observation and video observation, etc. We have succeeded in observing coral distribution including viability determination along with more than 1 km boat track of a glass-bottom-boat in Taketomi-island, Okinawa, Japan.

Keywords: coral, fluorescence, monitoring, laser, lidar

Fossil corals record 6000 year history of typhoon activity in the Northwest Pacific

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Prediction of future typhoon activity is important for determining their role in ecological disturbance and economic loss. Recent increase in sea surface temperatures (SSTs) caused by anthropogenic impacts has led to an increase in intense typhoons. However, instrumental records of typhoon are too short and unreliable to reveal trends in the typhoon activity. Understanding long-term variability of past typhoons is important for assessing whether changes in the variability are induced ongoing increase in SSTs. Fossil tabular corals preserved in raised reef coast offer new indicator to understand the variability of past typhoon intense. This study presents a record of typhoon activity in the Northwest Pacific over the past 6000 years based on fossil tabular corals (*Acropora digitifera*) from Kikai Island in the Ryukyu Islands that are characterized by the variability of size related to typhoon intense. The record indicates that the frequency of typhoon has varied on millennial scales over this period; it weakened during the mid Holocene climatic optimum and it strengthened over the past 2000 years. The variability of typhoon intense was correlated with the strength of El Nino-Southern Oscillation (ENSO) during the past 6000 years. This data suggests that it is important to understand the variability of ENSO and locations of genesis of typhoon for prediction of the change in typhoon activity near future. Therefore, the information implies that recent increases in SSTs are probably not the important drivers of typhoon activity.

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Keywords: typhoon, fossil coral, Kikai Island, ENSO

Ocean acidification impacts on coral biodiversity and productivity

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Introduction

Threatening of coral reefs by the climate change induced ocean acidification is now one of the biggest issues in the ocean ecosystem. Ocean acidification decreases the calcium carbonate saturation station, which result in the decrease of calcification rate of many calcifiers (Gattuso 1998, Kleypas 2004). Otherwise, the increase of seawater pCO₂ is predicted to increase the photosynthesis rate of phytoplankton and algae. Additionally, the seawater pH change will potentially affect the acid-base balance of marine organisms and impact their metabolic activity. In this study we focused on corals, and we experimentally evaluate the effects of ocean acidification on their physiology (calcification / photosynthesis / respiration). By integrating the future climate changing models and present results, we will discuss the potential impacts of ocean acidification on the coral biodiversity and productivity.

Methods

Three branching coral species from the family Acroporidae (*Acropora digitifera*, *A. tenuis* and *Montipora digitata*), and one encrusting coral species from the family Siderastreidae (*Psammacora contigua*) were collected from the patchy reefs in Okinawa island. All these species are highly common in the indo-pacific coral reefs. Several nubbins or mass of corals were taken from different colonies (5~10) and cultured for about one month under 3 different seawater pCO₂ conditions (380 ~2,300 ppm). These CO₂ conditions were selected according to the IPCC2007 models. All cultures were conducted under natural light conditions and flow through system. The seawater chemistry (pH, total alkalinity, salinity, temperature) was measured every day. Buoyant wet-weight was measure every week, and the physiology (calcification / photosynthesis / respiration) was measured at the end of culture using total alkalinity (TA) and total inorganic carbon (DIC) measurement technique.

Results and discussion

The sensitivity of corals to the ocean acidification was highly diverse among species. While *Montipora digitata* showed the highest decrease on calcification rate, *Psammacora contigua* show less sensitivity and *A. digitifera* was completely insensitive to high CO₂. Additionally, light and dark calcification rate were differently affected between species, and we suggest that dark calcification is possibly one of the keys that dominate the sensitivity of corals to the ocean acidification.

Photosynthesis rate of most corals was not affected by ocean acidification. Otherwise, the respiration rate of both *A. tenuis* and *P. contigua* increase with seawater pCO₂ rise. Since the metabolic activity of corals highly influence the seawater carbonate chemistry, these physiological impact induced by the ocean acidification is suggested to feed back on the reef water carbonate chemistry and may change the coral reef carbon cycle. Additionally, the species-specific response of corals to the ocean acidification is suggested to change the coral community structure and may result in the decrease of coral reef biodiversity.

The stable isotope composition of reef-dwelling foraminifers subjected to varied pCO₂ seawater

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Ocean acidification in response to rising atmospheric pCO₂ is generally expected to reduce rates of calcification by reef calcifying organisms, with potentially severe implications for coral reef ecosystems. Various studies have revealed potentially dramatic responses in a variety of calcareous organisms to the range of pCO₂ values projected to occur over this century. In our previous culture experiment with reef-dwelling foraminifers, *Amphisorus kudakajimensis* and *Calcarina gaudichaudii* at five different pCO₂ conditions seawater for four weeks, net calcification of *A. kudakajimensis* was reduced under higher pCO₂, whereas calcification of *C. gaudichaudii* generally increased with increased pCO₂. The contrasting responses are possibly due to differences in calcification mechanisms, but the factors affecting these calcification mechanisms are poorly understood. In this study, to get better understanding of the effect of ocean acidification on foraminiferal calcification, we cultured three reef-dwelling foraminifers: *Amphisorus hemprichii*, belong to imperforate species, *Baculogypsina sphaerulata* and *C. gaudichaudii*, belong to perforate species, using same experiment systems in the seawater of five different pCO₂ conditions for twelve weeks and we address the response of carbon and oxygen isotope compositions of the carbonate shells of foraminifers. Oxygen isotope value of cultured foraminiferal tests under five varied pCO₂ seawater indicated no significant correlation to pCO₂ values. The oxygen isotope values stay constant within narrower range from carbonate ion concentration. On the other hand, carbon isotope of foraminiferal tests indicated heavy trend with rising pCO₂ in all species. Alteration of carbonate chemistry result from ocean acidification may be effect strongly on carbon isotope composition relate to metabolic system. In perforate species, carbon isotopes are close to DIC value with increasing CO₂. It is possible that decreasing of metabolic CO₂ supply for the shell construction. In perforate species, both of oxygen and carbon isotope was lower than that in imperforate. For oxygen isotope variation possibility among species would be caused by their Mg-content concentration in calcite shells. The distinct difference in the level of carbon isotope values between pure calcite and perforate foraminifera might be influenced by the degree of dependency on metabolic CO₂ used for shell construction. While ~7% of the carbon used for calcification would be derived from respiratory for the perforate species, the imperforate species would use most carbon derived from bicarbonate ion of seawater directly because carbon isotope of shell is almost same to that of pure calcite. This study suggested that oxygen and carbon isotope of foraminiferal test have the potential to reveal difference in calcification mechanism of two species.

Keywords: stable isotope, reef-dwelling foraminifera, ocean acidification

Projected shift of coral habitats around Japan under different future CO₂ emission scenarios

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We estimate the effects of both global warming and ocean acidification on potential habitats for corals around Japan under different future CO₂ emission scenarios (SRES A2 and B1), based on published estimates and newly developed datasets on sea surface temperatures (SSTs) and aragonite saturation states (OMEGA_{arag}). The difference in the future coral habitats caused by higher SSTs and lower OMEGA_{arag} between the two scenarios was significant, suggesting possible conserve coral habitats under the A2 and B1 scenarios, respectively. We conclude that both reducing CO₂ emissions and setting up conservation plans to reduce direct anthropogenic effects would be required to save corals in the future.

Keywords: Coral, Global warming, Ocean acidification, Climate model, CO₂ emission scenario

Temperate coral reefs and coral communities and their recent changes

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Latitudinal gradients of coral reef geomorphology and coral communities are observed in Japan, as it covers a wide latitudinal range, stretching from subtropical to temperate areas. While the northernmost coral reef was found in Iki Island, Nagasaki Prefecture, coring and age determination revealed existence of a coral reef at a higher latitude, Tsushima Island (Yamano et al., 2012; Geology). The coral reef was composed of faviid corals, which shows substantial difference from coral reefs in tropical and subtropical areas with acroporid corals. Recently, settlement of warm-temperate species, *Acropora solitaryensis* was observed in the vicinity of the coral reef. Data mining of coral occurrence from the 1930s showed poleward range expansion of not only *A. solitaryensis* but also tropical-subtropical species, *A. muricata*, *A. hyacinthus* and *Pavona decussata* (Yamano et al., 2011; GRL). The maximum speed of the range expansions was 14km/year. Warming sea surface temperatures in the last century was attributed to the expansions. Corals are some of the world's most important species, being not only primary producers, but also habitat-forming species, and thus fundamental ecosystem modification is expected according to changes in their distribution.

Keywords: coral, poleward expansion, global warming

Biodiversity of upper mesophotic coral community in Okinawa.

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Mesophotic coral ecosystems (MCEs) are usually found at depth ranging from 30 to over 100 m depth. Mesophotic coral communities are often composed of both eurybathic tolerant species and species adapted to specific condition of the mesophotic zone. The taxonomic composition of such communities is still poorly known, yet important to conduct accurate paleoenvironmental interpretations of fossil reef deposits, especially in studies aiming to reconstruct past sea-level changes. Moreover, from a biological perspective, the Deep Reef Refugia Hypothesis (DRRH) states that mesophotic coral ecosystems, due to their more stable environmental conditions, may act as refugia for shallow water species to survive extreme climatic events and re-colonise shallower reefs in the future.

Recent global environmental changes affected seriously shallow coral reefs around Okinawa. The combination of major bleaching events and several typhoons lead to changes in coral communities with some species apparently extinct from several locations. Around Sesoko Island in the northern part of Okinawa, several corals species disappeared since 1999 and were not recorded since then (van Woesik et al. 2011). *Seriatopora hystrix* was one of those species.

During the recent survey of a mesophotic coral ecosystem located between Sesoko Island and Motobu Peninsula, high coral diversity and dense communities were found between 35 and 55 m depth including abundant populations of *S. hystrix* between 39 and 47 m. In order to estimate the coral biodiversity as well as the relationships between shallow and mesophotic corals, several genetic markers, both nuclear and mitochondrial, were sequenced for the samples collected. Symbiotic dinoflagellates were also identified. Here we will present the results of the molecular analyses showing the important coral diversity in this location. Our results also show intraspecific diversity within the population of *S. hystrix*. The genotypes of those deep populations correspond to genotypes previously observed from shallower reefs as well as to new genotypes. Such results suggest an absence of vertical structuring in Okinawan *S. hystrix* populations and support the (DRRH). In the future, and if shallow environmental conditions become suitable again for this species, deep populations of *S. hystrix* might be of critical importance for the re-colonisation of shallow coral reefs.

Reference: van Woesik R, Sakai K, Ganase A, Loya Y (2011) Revisiting the winners and the losers a decade after coral bleaching. *Mar Ecol Prog Ser* 434: 67-76

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Keywords: Mesophotic, Deep Reef Refugia Hypothesis, Seriatopora

Use of the isotope ratio of dissolved inorganic carbon for investigating the carbon cycle of coral reef ecosystems

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The isotopic composition of dissolved inorganic carbon ($d^{13}C_{DIC}$) has been determined for reef waters collected at subtropical coral reefs of Ishigaki Island, western North Pacific. Short-term (6 - 24 h) observation has been conducted several times at several different communities in summer (September) and winter (January). $d^{13}C_{DIC}$ varied between -0.2 and +3.2 per mil (vs. VPDB). Temporal pattern of $d^{13}C_{DIC}$ was significantly different between winter and summer, with the diurnal variation being much larger in summer. Both the concentration of DIC (c_{DIC}) and the alkalinity (A_T) decreased while the $d^{13}C_{DIC}$ increased during daytime due to active uptake by photosynthesis and calcification of reef primary producers. The opposite temporal pattern was observed at night. The gradient of the c_{DIC} - $d^{13}C_{DIC}$ regression line was almost same for different coral communities and seagrass beds. However, the gradient of the A_T - $d^{13}C_{DIC}$ regression line was somewhat larger for seagrass beds and *Heliopora*-dominated communities than for branching coral-dominated communities, possibly reflecting difference in the isotope fractionation by photosynthetic uptake of DIC. The $d^{13}C_{DIC}$ at a given c_{DIC} or A_T was constantly lower for the seagrass beds than the coral communities, which could be ascribed to the addition of groundwater DIC to the seawater of nearshore seagrass beds. The overall results suggested that, by carefully correcting for the difference in the isotope fractionation during uptake processes and incorporating into an appropriate numerical model, the c_{DIC} - A_T - $d^{13}C_{DIC}$ systematics can be used for simultaneous quantitative evaluation of the magnitudes of photosynthesis, calcification, respiration, and input of exogenous DIC such as groundwater DIC at coral reefs.

Keywords: coral, seagrass, carbon isotope, DIC, isotope fractionation, groundwater

Climate change influences on coral growth tested by a culture experiment of temperate species

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Recently, it has been reported that rising temperature of sea surface by global warming causes quick poleward range shift and/or expansion of some coral species around Japan. This is probably because the influences from not only rising temperature by global warming but also ocean acidification. The ocean acidification has been decreasing pH and Omega (saturation state of CaCO₃) in seawater, which would cause negative impact on calcification in coral skeleton composed of CaCO₃ (aragonite). However, the influences of climate changes on "expanded" corals and corals, which are distributed in northern limited, have not yet been tested in detail. In this study, we focus on the corals distributed in the temperature zone and conducted culture experiment on these corals in order to reveal the impacts of global warming and ocean acidification on coral growth.

To evaluate coral growth by enhanced global warming and ocean acidification followed by continuous CO₂ emission, two culture experiments, "Temperature experiments with large Omega gradient" and "Temperature experiments with normal Omega gradient", both of which have 5 temperature settings, were conducted. "Temperature experiments with large Omega gradient" had Omega of 3.1 - 1.8, which were from high to low temperature, as a result of adjusting partial pressure of carbon dioxide (pCO₂) to achieve constant pCO₂ concentration throughout all temperature settings. In contrast, "Temperature experiments with normal Omega gradient" had Omega of 2.4 - 2.1, which were little change with temperature because of no addition of CO₂ in all temperature settings.

The results of both two culture experiments showed that all coral species were bleached and died at 13 deg C treatment, suggesting that low temperature of seawater during the winter season could be a limited factor of northern distribution of temperate corals. On the other hand, suppression of coral growth according with the decreasing of carbonate saturation state indicated that ocean acidification effect could also be negative influence on calcification of corals. Recent modeling study provided a prediction in which the distribution of temperate coral around Japan might be limited by ongoing ocean acidification rather than increasing seawater temperature. Our experimental study suggests that the growth rate of temperate corals are potentially affected by decreasing Omega and that expansion of temperate corals towards the north accompanying with global warming would be suppressed by ocean acidification in the near future.

Keywords: coral, global warming, ocean acidification

Supratidal beach sediment cores as recorders of long-term environmental and ecological changes in coral-reef ecosystems

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Coral reef ecosystems have been degraded worldwide. Modeling and culturing studies have been conducted to predict future outcomes of coral reef ecosystems. However, few studies conducted long-term (10-100 years scale) environmental changes and associated ecological changes in coral reef ecosystems, data on which would provide insight into long-term effects of global environmental changes and anthropogenic impacts on coral reef ecosystems. Here we focused on supratidal sediment cores as potential recorders of long-term (10-100 year scale) environmental and ecological changes in coral reef ecosystems. Approximately two-meter sediment cores were taken from supratidal zones of Sesoko Beach (Sesoko Island, Okinawa) and Yakomo Beach (Okinoerabu Island, Kagoshima). Sedimentary structure, grain size composition, bioclastic composition, and radiocarbon ages of bioclasts (coral/mollusk/foraminifer) were examined. Based on sedimentary features and grain-size variations, cores were divided into three parts (lower, middle and upper units), each of which indicates intertidal, storm, and aeolian deposits, respectively. Radiocarbon ages of coral fragments suggest that the two-meter cores were deposited in recent times (after 1950 yr AD). Bioclastic compositions indicate no ecological changes since the deposition of these cores. The shell morphology and weight of *Baculogypsina* (symbiont-bearing hyaline foraminifers) indicate that the modern tests grew larger and heavier than fossil tests (ca. 1300 yr AD), which are possibly due to biological consequences of ocean acidification and global warming.