The effects of latitude on mangroves inferred from forest structure and productivity in the Ryukyu archipelago

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Mangrove is one of the unique ecosystems in subtropical and tropical coastal regions. Mangroves provide various ecosystem services, such as wood production, supporting coastal food webs and nutrient cycles in adjacent coastal ecosystems, carbon accumulation, trapping sediment and tsunami reduction. On the other hand, mangroves are one of the world's most threatened tropical and subtropical ecosystems and are being degraded in most countries mainly caused by anthropogenic activities and unsustainable exploitation. Ecology in plant production can give an insight into the basic mechanism supporting the ecosystem services with a viewpoint from forest structure and function.
This presentation focuses on the structure and productivity of mangroves around the Ryukyu Archipelago where the forest structure and function change drastically along a latitude since the study region is located around the northern distribution of mangroves. The effects of latitude on mangroves in East Asia will be discussed with some results based on the field researches conducted in the Ryukyu Archipelago.

Keywords: Production ecology, Biomass, GPP, NPP

Net uptake of atmospheric CO_2 in human-dominated estuarine and shallow coastal systems: empirical studies and the ecosystem modeling

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Estuarine and shallow coastal systems (ESCS) are recognized as not only significant carbon reservoirs but also net emitters of CO_2 to the atmosphere, posing the dilemma of how ESCS functions relate to climate change mitigation. However, some studies have shown that ESCS take up atmospheric CO_2. Here we reviewed empirical studies and developed a new ecosystem model to investigate the magnitude and determinants of net uptake atmospheric CO_2 by ESCS. We found that the capability of ESCS to function as CO_2 sinks is enhanced by environmental conditions that are typical of human-dominated systems (e.g., input of high terrestrial nutrients, input of treated wastewater in which labile carbon is highly removed, and presence of hypoxia).

Keywords: Blue Carbon, Climate change, Ecosystem model

Field observations and the path analysis of CO_2 fugacity in shallow coastal waters of Japan

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The Blue Carbon, which is carbon captured by marine living organism, is recently recognized as an important option for climate change mitigation initiatives. In particular, shallow coastal waters such as seagrass meadows, tidal flats and coral reefs have been recognized as significant carbon stocks due to the high burial rates and long term sequestration.
In this study, using the path analysis, we investigated the mechanisms by which environmental factors directly and indirectly affecting the fugacity of CO_2 in water. Field observations were performed to examine the fugacity of CO_2 in water and environmental factors (e.g., water temperature, salinity, total alkalinity (TA), dissolved inorganic carbon (DIC), the metabolism (Δ DIC) and calcification (ΔTA)) in shallow waters. In situ measurements were conducted at boreal (Furen and Komuke lagoon), temperate (Hashirimizu coast, Nojima waterway, Matsuwa, Banzu and Futtsu tidal flat), and subtropical (Fukido estuary, Shiraho coast and Nagura Bay) sites in 2010~2015. In addition, we implemented the path analysis to infer important environmental factors and interactions affecting the fugacity of CO_2 in water.

Keywords: blue carbon, the fugacity of CO2 in water, seagrass meadow, tidal flat, coral reef, path analysis

Seagrass biomass as a controlling factor of organic carbon stocks in subtropical seagrass meadows

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Carbon sequestrated in marine ecosystems has been termed “blue carbon”, and seagrass meadows are one of the most dominant blue carbon stocks. Globally, one of the major distribution sites of seagrass meadows is coral reef flat. Recent studies have revealed that the amount of sedimentary organic matter in tropical and subtropical coasts is comparable to that in temperate coasts. However, these estimations are based on a few data and have wide range. Since quantifying organic carbon in the carbonate sediment is technically difficult and costly, easier methods for estimating the amount of organic carbon in seagrass meadows are strongly needed to assess the global blue carbon stocks for mitigation of global warming. Seagrass biomass is suggested to have responsible for the variability of seagrass carbon sink capacity, but the models have not been presented yet. To identify the relationship between seagrass biomass and blue carbon stocks, we developed a new box corer which can facilitate to obtain the intact cores structured by both sediments and seagrass bodies. Using the core samples taken in subtropical seagrass meadows and adjacent unvagetated areas, located around Ishigaki Island, Japan, we measured total organic carbon mass (TOC_{mass}) and the stable isotope ratios ($\delta^{13}C$) of total sedimentary organic matter and then conducted regression analyses between organic carbon stock and seagrass biomass. The averaged TOC_{mass} of the top 15 cm sediment including live seagrass biomass was 876 ±408 g C m^{-2} (n = 28). The live seagrass biomass accounted for 17 ±15 wt%, whereas the dead plant structures (>2 mm), coarse sediments (>1 mm except for dead plant structures >2 mm) and fine sediments (<1 mm) accounted for 4 ±4 wt%, 21 ±14 wt%, and 58 ±15 wt%, respectively. TOC_{mass} increased with increasing the above seagrass biomass (A_b [g DW m^{-2}]) (TOC_{mass} = 5.92 A_b + 502, R^2 = 0.72, n = 28, p < 0.01). The above seagrass biomass was one of the controlling factors of blue carbon stocks at the sites.
Sedimentary organic carbon mass (mixture of the dead plant structures, coarse sediments and fine sediments) was also positively correlated with the above seagrass biomass (R^2 = 0.45, n = 28, p < 0.01). Using a Bayesian isotopic mixing model, we estimated that the contribution of seagrass-derived carbon to total sedimentary organic carbon was about 70%. The median values of seagrass-derived carbon mass estimated by the model was positively correlated with the above seagrass biomass (R^2 = 0.46, n = 28, p < 0.01), whereas those derived from terrestrial POM or suspended POM had no correlation with the above seagrass biomass. Consequently, the enrichment of sedimentary organic carbon with increasing the live seagrass biomass was mainly due to accumulation of seagrass-derived organic carbon at the sites. These results suggest that blue carbon stocks can be increased by the conservation and restoration of seagrass meadows in subtropical coasts.

Keywords: carbon stock, blue carbon, seagrass meadow, isotopic analyses, coral reef

Total alkalinity flux at seagrass meadow estimated by eddy covariance and pore water profiles in sediment

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Ocean acidification decreases the pH of seawater and the saturation state of minerals, and carbonate sediment dissolution could be more sensitive to ocean acidification than calcification by reef organisms (Eyre et al. 2014). Particularly in seagrass-carbonate sediment, it has been suggested that both abundant labile organic matter and wide redox range would increase pCO_2 in sediment, and total alkalinity (A_T) flux from sediment to water column caused by Mg-calcite dissolution would also increase. Here, we measured sedimentary dissolved oxygen (DO) and carbonate profiles in a seagrass area of Shiraho coral reef, Ishigaki Island, and A_T flux at the sediment-water interface was estimated using eddy covariance (EC). Almost half of the sediment was Mg-calcite derived from foraminifera and its Mg content was 16.4 mol%. Analysis of the sedimentary DO and Oxidation-Reduction Potential (ORP) profiles at night indicated that O_2 was depleted deeper than at least 4 mm and sulfate reduction could occur. While pore water A_T and dissolved inorganic carbon values increased with depth, pore water saturation state of aragonite was constant at a value of ~ 2.3 during the entire nighttime. On the other hand, the calculated nighttime A_T flux from sediment to water column was 0.9–3.2 mmol m^{-2} hr^{-1} though seawater in water column was oversaturated with respect to Mg-calcite. This would be caused by Mg-calcite dissolution and bacterial sulfate reduction, and A_T flux from sediment to water column would increase further by ocean acidification.

Keywords: Ocean acidification, Total alkalinity flux, Mg-calcite

Sustained eutrophic conditions in mariculture areas of Bolinao and Anda, Philippines as seen using biogeochemical indices including oxygen isotope of phosphate

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Long-term time series of nutrients in a monitoring station in Bolinao, Philippines showed persistently eutrophic conditions even after regulation in number of fish farm structures from 2002. Regulation was implemented following a massive fish kill that occurred in the coastal waters of Bolinao in the same year. To elucidate the reasons for this sustained eutrophication and determine their implications to management for the mitigation of recurring algal blooms, hypoxia and fish kills, the nutrient dynamics of nitrogen (N) and phosphorus (P) was studied for Bolinao and its adjacent coastal town of Anda.

Detailed spatial and temporal analysis of nutrients in the water column, sediments, and possible end member sources of nutrients to the mariculture area was conducted. Based on the results, mariculture areas exhibited high concentrations of dissolved inorganic nitrogen (DIN) especially ammonium (NH_4^+), and dissolved inorganic phosphorus (DIP) primarily due to decomposition of uneaten and undigested fish feeds, and fish excretions. Compared to the Redfield ratio (N/P of 16), these materials are enriched in P relative to N, resulting in low N/P ratios (~6.6) of the regenerated nutrients. DIP in the water was higher during the dry season than the wet season possibly due to enhanced accumulation of regenerated nutrients inside the embayment during the dry season due to the flow pattern. Temporal analysis of satellite images showed that while fish farm structures in Bolinao have been regulated, the structures in Anda continued to increase in number. This has contributed to fish farm-derived organic matter and regenerated nutrients enriched in P that can get advected to Bolinao waters with the residual currents during the dry season. These factors sustained the DIP enrichment and created an N-limited condition that is highly susceptible to sporadic algal blooms whenever N is supplied from freshwater input during the wet season.

Analysis of the ratio of the oxygen isotopes of phosphate ($\delta^{18}O_p$) from different environmental samples showed that rivers (14.4 ±0.2 ‰) and fish feed (21.8 ±0.4 ‰) are two contrasting end-member sources of phosphate to the mariculture areas. Sediment porewater (21.3 ±0.2 ‰) has a similar isotopic signature as fish feeds suggesting that porewater DIP mainly come from decomposed feeds. Water samples from mariculture areas showed $\delta^{18}O_p$ close to fish feed end-member values that vary depending on season and tidal variation.

Keywords: phosphorus, eutrophication, fish feed, nutrient ratios, mariculture, oxygen isotope ratio of inorganic phosphate

Stress responses of reef-building corals

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Over the past several decades, coral reef ecosystems have experienced various stresses and extensive degradation due to increased anthropogenic activity. Reef-building corals respond to stress in various ways (e.g. bleaching, etc.). Corals exhibit defense mechanisms such as mycosporine-like amino acids against stresses, although many of these functions have not yet been clarified. Understanding the defense mechanisms in corals could provide important information for finding solutions to stress-related responses such as coral bleaching. In this presentation, I describe coral bleaching, oxidative stress, antioxidant activities as responses and defense mechanisms against environmental stressors including high temperature, low temperature, eutrophication, and ultraviolet radiation.

Keywords: reef-building corals, stress response, coral bleaching

Glocal environmental effect at Palau coral reef ecosystem

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Introduction

Coastal ecosystem supplies a number of ecosystem services that sustain human society, however it is now threaten by multiple anthropogenic impacts. Our need to understand the degree of human impacts in coral reef ecosystem is principally essential in small reef island countries because reef health is directly linked to the sustainability of their economy. In this present study, we will focus on the Republic of Palau and evaluated the global and local environmental change on the reef ecosystem of Palau for the aim of getting information needed for better reef conservation and management.

Methods

Twenty two sites around the coast of Palau was selected and environmental parameters including temperature, salinity, dissolved oxygen, chla, turbidity, suspended solid, particle organic carbon (POC), particle organic nitrogen (PON), dissolved inorganic nutrient (DIN, DIP), total inorganic carbon (DIC), alkalinity, pH and aragonite saturation was measured at surface (0 m) and bottom (8 m). At the same time, the benthic coverage and coral community was evaluated by 5 transects of 10 m length for each sites. From these parameters, we evaluated the most important factors that regulate coral reef community.
Next, we focus on the two main climate change factor (temperature and pH), and evaluate the recent pH and temperature trend in Palau coast and study the possible impact on the coral community. Additionally, we focus on the sewage discharge on the reef, and evaluate the recent nutrient and Chla trend in Palau coast and evaluate the effect on the coral community.

Results and Discussions

From present results we found that the reef environment and coral community in Palau can be divided into three areas: north-west area, east area and lagoon and south area. The North-West area was characterized by Acropora dominant community with high pH (high aragonite saturation), the East area by Montipora and Pocillopora community with high pH (high aragonite saturation) and variable turbidity, and Lagoon and South area by Porites with low pH, and high nutrient and turbidity. From these results it is suggested that coral reef management should be focused on these 3 different areas, and pH, nutrient and turbidity are the important environmental factors that should be monitored. Additionally, we found that both pH and temperature is significantly increasing in the coast of Palau suggesting the progress of ocean acidification and global warming. Finally, we found that the continuous sewage discharge have increased the nutrient concentration by two times within these 20 years. Additionally, this environmental change is suggested to causing out break of COTS (Crown of Thorns Starfish), which might affect coral community. From these results, we suggest that local management together with the consideration of climate change, will be essential for management of Palau coral reef ecosystem.

Keywords: coral reefs, climate change, sewage discharge, coral community, management

Numerical simulation of typhoon events in Sekisei Lagoon, Okinawa, Japan

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Typhoons of sufficient intensity have been known to cause damage to coral reef ecosystems but may also bring benefit in the form of typhoon-induced cooling, which can mitigate against thermal stress. Sekisei Lagoon is the site of Japan's largest coral reef area and is also impacted to varying degrees by typhoons which approach yearly during the summer season. To closely investigate typhoon-driven hydrodynamics in Sekisei Lagoon, selected typhoon events were modeled using a nested Regional Ocean Modeling System (ROMS) configuration with an outer coarse scale regional model at 1.5 km grid resolution, and an inner model focused on the Sekisei Lagoon domain with a grid resolution of 300 meters. Ocean boundary forcing for the regional model was derived from global 1/12° Hybrid Coordinate Modeling System analysis data (HYCOM GLBa0.08). Meteorological forcing was derived from Japan Meteorological Agency-Grid Point Value (JMA-GPV) mesoscale model results. Model performance was evaluated by comparing simulation results with in-situ observations from sensor deployments around Sekisei Lagoon conducted during the summer months of 2013, 2014, and 2015. Sensor positions and durations varied between the deployments, but typhoon event field data at specific locations was available for model comparison for parameters such as water velocity, water level, temperature, and wave height. Analyses of field observations during typhoon passages revealed various typhoon related trends, such as sudden temperature downshifts, potentially destructive wave conditions, and enhanced water flow velocity, especially through channels. The timing, magnitude, and spatial patterns of such trends varied depending on typhoon track and intensity, and the ability of the model to reproduce these observed trends was assessed. The model results were then analyzed further in terms of modeled 3-D spatiotemporal trends both within the Sekisei Lagoon domain and the surrounding ocean areas to clarify the dominant physical processes involved in each specific event, such as the effects of strong vertical mixing due to typhoon winds, wind-driven currents, and the possibility of typhoon-driven upwelling of cold, bottom waters from offshore. The results of this investigation may give further insight into the ways in which typhoons affect the hydrodynamic conditions in Sekisei Lagoon, which are related to many aspects of the coral reef ecosystem, such as coral health and susceptibility to bleaching, larval dispersal, and physical damage from waves. Such information may help guide coral reef ecosystem management and conservation efforts to more properly account for the effects of typhoons.

Keywords: hydrodynamics, typhoon, ocean model, coral reef, sensors

History of Coastal Environment Recorded in Coral from Fongafale Island, Tuvalu

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Because of their low altitudes, atoll islands in Tuvalu, the South Pacific is concerned for the earliest influence of the sea level rise and resultant submergence caused by global warming. However the local environmental change such as land development and water pollution with recent increasing population also damages the ecosystem and the sustainability of coral reef islands. To examine the time series of anthropogenic impacts on the coastal reefs, we analyzed the coral annual bands obtained in 2009 from the lagoon of Fongafale Island, the capital of Tuvalu.
The coral core fg01 from living colonies of *Porites lutea* (core length; 78 cm) shows growth interruption at 20cm under the top and the characteristic black bands were observed along annual bands above that break. We introduced the age axis to fg01 using the Δ14C- annual bands correction constructed with the other continuous coral annual bands (fh11, core length; 93 cm, 1940-2009) from Funafala Island on the same atoll. The core fg01 started the growth from 1940-50s and the discontinuous period was for 1970s-1990s, after that the coral has restarted its growth but the black bands pollution is conspicuous.
To identify this pollution we performed organic/ inorganic analysis and studied a microscopic inspection. We found high dense fibers of boring microbes; some kinds of algae and fungi in the black bands of coral skeleton. The propagation of microbes into the feeble coral skeleton and the construction of the black bands started from 1990s, which was coincident with increase of living drainage caused by densely population at Fongafale Island (*Yamano et al*.,2007, *Fujita et al* .,2013, 2014). Further the construction of the black annual bands suggests the seasonal propagation of microbes related to coastal environment.
On the other hand, in the process of the organic analysis using GC/MS we detected the higher concentration of petroleum hydrocarbons from the bottom of the coral core corresponded to 1940-50s annual bands than the upper part. The low CPI value (Carbon Preference Index; a rate of diagenesis) suggests this hydrocarbon was used as fuel for heavy equipments introduced during the World War II. Fongafale Island has the history that the US Army built a heavy bomber-runway for one month in 1943.
70yr coral annual bands from Fongafale Island recorded both the trace of the World War II and recent human impact in that skeleton.

Spatiotemporal variation in carbon and nitrogen stable isotope ratios of suspended and settling particles in coral reefs

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Particulate organic matter (POM) is an important carrier of energy and nutrients in oligotrophic aquatic environments such as coral reefs. Major nutrient elements including carbon, nitrogen, phosphorus, silicon, and iron can be transported in the form of sestonic POM by coastal currents from open ocean to coral reefs, where they are captured by particle-feeding organisms, or settle down and are consumed by deposit feeders and microorganisms. Concomitantly, coral reefs produce a variety of POM such as coral mucus and plant detritus, and export them back to the outer ocean. POM also provides a means of material exchange between different habitats within the ecosystem, such as coral-covered reef slope, algal pavement, back-reef lagoon, and seagrass meadows. Elucidating the dynamics of suspended and settling POM is essential to understand functioning, stability, and resilience of the coral reef ecosystem. In this study, we evaluated the variability of the concentration and the carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) stable isotopic compositions of POM in various locations and different seasons at two coral reefs (Shiraho and Itona coasts) of Ishigaki Island, southwest Japan. Depositional flux of POM to several different habitats within the reefs was also estimated using sediment traps. The concentration of POM in the outer ocean was low (<5 μ mol POC L^{-1}) with $\delta^{13}C$ ranging from −24‰ to −19‰ and $\delta^{15}N$ from +3‰ to +5‰. The concentration of POM was elevated in the reef system, especially around seagrass meadows (up to 50 μmol POC L^{-1}). Suspended and settling POM collected within coral-covered habitats showed typically higher $\delta^{13}C$ (−18‰ to −12‰) and slightly lower $\delta^{15}N$ (0‰ to +5‰) than the offshore POM, reflecting contribution of autochthonous organic matter. Suspended POM collected in the nighttime at coral-covered areas sometimes showed much higher $\delta^{15}N$ (+7‰ to +9‰) indicating an accumulation of zooplankton in the water column. The $\delta^{13}C$ and the $\delta^{15}N$ of POM collected in bare sanded backreef lagoon were usually in the midst of POM collected in the offshore and the coral covered areas. The $\delta^{13}C$ of POM in the overlying water of seagrass meadows was even higher than that in the coral-covered habitats, occasionally exceeding −10‰. Both the sinking flux of POM and the $\delta^{13}C$ of sinking POM were generally higher in summer than in winter. Endmember $\delta^{13}C$ and $\delta^{15}N$ values of source organisms including hermatypic corals, zooxanthellae, seagrasses, seagrass epiphytes, and macroalgae as well as some particle- and deposit-feeding organisms have been separately determined. Comparison of POM and these endmembers suggested that contributions of these internal and external (offshore) sources to the POM pool at particular habitats varied depending on location of the habitats, season, tidal cycle, and diurnal cycle. Using these data, we discuss potential importance of nutritional linkage by the transport of POM between the outer ocean and corals and between different habitats such as corals and seagrass meadows.

Keywords: particulate organic matter, coral reefs, seagrass beds, sinking flux, provenance analysis

