Preventing red-soil runoff in the Ryukyu Islands, Japan, considering biodiversity and environmental economics

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After the reversion of Okinawa (Ryukyu Islands) to Japan in 1972, extensive urban and agricultural development resulted in a significant increase in red-soil discharge to coastal waters. The release of red-soil has caused the degradation of freshwater and coastal ecosystems and biodiversity. A consideration of catchment-to-reef continua, as well as agricultural (socioeconomic) factors is necessary for establishing proper land-based management plans for the conservation of the island environment. We have set up a framework to integrate biophysics and socioeconomics: 1) setting a conservation target and threshold, 2) identifying the sources and processes, and 3) examining cost-effectiveness and management priorities. The framework was applied to Kume Island, Ryukyu Islands.

Land-sea pathways between snowmelt and fishery production

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Cultured scallop (*Patinopecten yessoensis*) is a typical coastal fishery in Funka Bay. The annual spat density of scallop is highly correlated with the snowmelt runoff or accumulated snowfall. We investigated the land-sea pathways in Funka Bay, Japan, a typical semi-enclosed bay during snowmelt period to understand how the snowmelt runoff can improve the spat density or production of scallop larvae associated with ocean primary production, by analyzing hydrological and oceanographical data produced by a land-sea integrated model in conjunction with newly compiled datasets of riverine nutrient concentrations and of the particle tracking simulation. The model successfully estimated the riverine dissolved inorganic nitrogen (DIN) flux that is dominated by the temporal variation of the river runoff rather than that of the riverine DIN concentration. Ocean simulation indicated that the freshwater flux supplied by the snowmelt runoff enhances the clockwise circulation along the coast of the bay. The close relationship between the annual spat density of scallop and the snowmelt runoff associated with high DIN concentrations can be explained as follow; riverine nutrients can increase the biomass of phytoplankton in near-shore seas and improve food availability for scallop spawners, resulting in increased egg production in March to April. Therefore, the nutrient flux from agricultural source areas through the large snowmelt runoff has an important role in larvae production. Land-sea pathways need to be identified to design sustainable and synergetic systems of aquaculture and agriculture for the integrated management of coastal regions.

Keywords: Land-sea pathway, Snowmelt runoff, Nutrients, Coastal fishery prodcution

Evaluation of submarine groundwater discharge in a ria coast at the eastern Kyushu island using Rn isotopes

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Ria coast is thought to have a high potential for groundwater discahrge adn related nutrient fluxes from land to coastal sea due to a topgraphic property. However, there is little knowledge about submarine groundwater discharge in ria coast in Japan. In this study, we have evaluated the rate of submarine groundwater discahrge and associated nutrient fluzes in the small coastal embayment along the ria coast at the eastern Kyusyu uinsg ^{222}Rn.

Keywords: Submarine groundwater discharge, Ria coast, 222Rn

Seasonal variation in dissolved and particulate nutrient delivery from two subtropical mangroves to outer ocean

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Estuarine mangroves enhance longitudinal mixing of seawater and freshwater and actively exchange nutrient materials such as carbon (C), nitrogen (N) and phosphorus (P) with the water phase. Mangrove vegetation takes up and fixes atmospheric CO_2 by photosynthesis, and some of the fixed carbon is sequestered within the sediment for a long term, while the other part is released later as respired CO_2 and detrital organic C (OC) into river and sea water and eventually exported to the outer ocean. The released OC fuels heterotrophic animal and microbial communities inside and around the mangrove, and the exported CO_2 locally enhances ocean acidification in coastal ecosystems. Mangroves are also known as a nutrient filter that captures and removes dissolved inorganic N (DIN) from river water by denitrification, thereby preventing N loading to coastal ocean. In subtropical mangroves, inherent biological activities of mangrove ecosystems, such as photosynthesis, remineralization, and denitrification, as well as external nutrient inputs to mangroves through river waters or atmospheric deposition, can vary widely depending on seasons. However, knowledge about seasonal variability of ecosystem functioning of mangroves is still very limited, especially for subtropical ones. We investigated biogeochemical properties of two subtropical estuarine mangroves of Ishigaki Island, Okinawa, Japan, with an emphasis on seasonal variability. Intensive water sampling was conducted at mangrove-ocean interfaces and several streams flowing into the mangroves in different seasons (March, June, September, and December), and concentrations and isotopic compositions of dissolved and particulate constituents were determined to create and compare the salinity-property diagrams. Mangroves were always a net source of dissolved inorganic C (DIC) to the water phase. The $\delta^{13}C$ of DIC in the brackish zone was more negative in warmer seasons, indicating temperature dependence of soil respiration. Nitrate dominated in DIN in river waters. Dissolved inorganic P (DIP) usually behaved conservatively across the salinity gradient, while the mangroves seemed to be a net sink for nitrate and a net source of nitrite and ammonia. The ratio of DIN to DIP was the lowest in March. In most cases, the weight ratio of particulate organic C (POC) to chlorophyll *a* exceeded 500, indicating the predominance of detrital organic matter produced within the mangroves. The ratio of POC to particulate N (PN) was the highest and the $\delta^{13}C$ of POC was the most negative in December. The $\delta^{15}N$ values of both nitrate and PN in the brackish zone was higher in warmer seasons, which suggested that denitrification in the watershed and the mangrove depended on temperature. Our results suggested that the ecosystem functioning of subtropical mangroves vary significantly between different seasons, and that such a seasonal variation could be due to seasonal changes in both internal metabolic activities and external factors such as hydrology and nutrient loading from the watershed. We discuss these characteristics of subtropical mangroves in comparison with mangroves under different geographical and climate conditions.

Keywords: Mangrove, Dissolved inorganic carbon, Dissolved inorganic nitrogen, Particulate organic matter, Salinity gradient, Stable isotope ratio

Testing Hydrological Suitability for Mangrove Restoration in Vietnam and Indonesia

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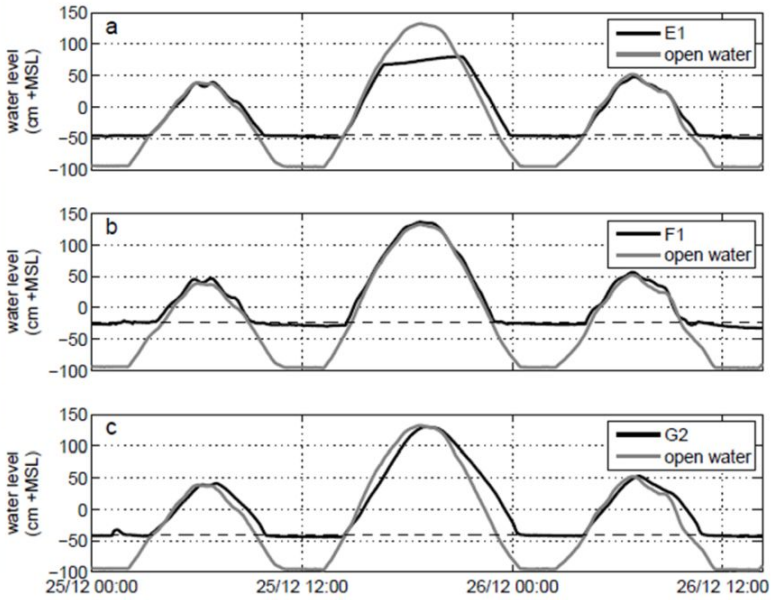
Mangrove restoration projects, aimed at restoring important values of mangrove forests after degradation, often fail because hydrological conditions are not properly restored. We present a simple, but robust methodology to determine hydrological suitability for mangrove species, which can guide restoration practice. In 15 natural and 8 disturbed sites (i.e. disused shrimp ponds) in three case study regions in south-east Asia, water levels were measured and vegetation species composition was determined. Using a hydrological classification for mangroves, sites were classified into hydrological classes, based on duration of inundation, and vegetation classes, based on occurrence of mangrove species. In the natural sites, hydrological and vegetation classes were similar, showing a clear differentiation of mangrove species between wet and dry sites. Application of the classification to disturbed sites showed that in some locations hydrological conditions had been restored enough for mangrove vegetation to establish, in some locations hydrological conditions were suitable for various mangrove species but vegetation had not established naturally, and in some locations hydrological conditions were too wet for any mangrove species (natural or planted) to grow. We quantified the effect that removal of obstructions such as dams would have on the hydrology and found that failure of a restoration project at one site could have been prevented. In this presentation we will discuss the use of a hydrological classification in mangrove restoration projects compared to using elevation only. We conclude that the hydrological classification gives important information about how to restore the hydrology to suitable conditions to improve natural regeneration or to plant mangrove species, which could not have been obtained by estimating elevation only. Based on this research a number of recommendations are given to improve the effectiveness of mangrove restoration projects.

Keywords: mangrove, restoration, hydrological classification, Vietnam, Indonesia



Heat-flux from the submarine groundwater discharge at the coastal area: A case from the Obama Bay, Japan

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Various studies regarding submarine groundwater discharge (SGD) have been performed. Although SGD has been recognized as an important pathway for nutrients transport from land to coastal ocean, SGD also supplies other chemical compositions as well as heat in the form of thermal energy. Especially, there is a difference in water temperatures of SGD and seawater, since groundwater temperature is almost constant throughout the year and seawater temperature varies. However, it is not clear that how much heat energy is supplied by SGD and its associated impacts on coastal ecosystems. Several studies assessing the impact of drainage water from the power plants have indicated that the water temperature has a significant impact on the coastal ecosystems. It highlights the need for assessing the impact of SGD on coastal ecosystems not only by considering the nutrient influx but also by giving equal importance to inflow water temperatures. To investigate this hypothesis, we undertook a study in a coastal area of Obama Bay, Fukui Prefecture, Japan.
In Obama Bay, SGD rate has been estimated using ^{222}Rn and salinity mass balance model (Sugimoto et al., 2016). We calculated the heat quantity from SGD by using the formula [E = Q * Cp * ΔT], where, E is the heat quantity from SGD; Q is the SGD rate from Sugimoto et al. (2016); Cp is the specific heat at constant pressure; and ΔT is the difference between seawater and groundwater temperatures. The following results are obtained from this study: The SGD resulted in hot and cold heat influx to the coastal areas during winter and summer seasons, respectively. Although SGD rate is observed much less than the river discharge, cold heat flux from SGD was greater than the river during summer. SGD resulted in lowering the sea water temperature at the bay during the summer. In this presentation, we will additionally discuss about the magnitude of this heat-flux as compared to the results of SGD heat-flux at another study site.

Keywords: submarine groundwater discharge, heat flux, coastal area

Location estimation of submarine groundwater discharge from Mt. Fuji in Suruga Bay(IV)

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Around the foot of Mt. Fuji, the main flow passages of groundwater are thought to be in the Younger Fuji volcano, which consists of the pervious basaltic lavas in new volcanic stage. Most of rainfall and melted snow have been considered to be percolating into underground, turning to groundwater, flowing down in the layers of the Younger Fuji volcano and partly discharging from seabed in Suruga Bay. Especially, the Fujikawa-kako fault zone, which stretches south to north in the southwestern side of Mt. Fuji, has a potentially effect on the local groundwater flow system into Suruga Bay. Therefore, precipitation at Mt. Fuji have been considered to be discharging partly from seabed in Suruga Bay and making a impact on the biological production at the coastal sea area.
For the purpose of contribution to make sense of the rich coastal ecosystem in Suruga Bay, we conducted a survey for submarine groundwater discharge (SGD) in Oku-Suruga Bay: from the mouth of the Fuji River, at which the fault is found, to Tagonoura, where the lavas of the Younger Fuji volcano are distributed from 100 to 200 m below sea level. We tried to estimate some locations of SGD from bottom topography, condition of seabed and geological structure by using multibeam sonar, side scan sonar and sub-bottom profiler, respectively. We also used a remotely operated vehicle (ROV) for photographing for the image of the extrapolated spring points, sampled seawater containing sea bottom spring water and conducted water quality analyses. In this presentation, we introduce our works noted above.

Keywords: submarine groundwater discharge (SGD), Mt. Fuji, remotely operated vehicle (ROV)

Influence of submarine groundwater discharge on phytoplankton primary productivity at nearshore coasts in Beppu Bay and Otsuchi Bay

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In recent years, a number of studies have shown that submarine groundwater discharge (SGD) is an alternative nutrient pathway and can drive primary production in coastal seas. However, little is known about a relationship between input of nutrients through the groundwater and response of primary production. To clarify the relationship, we conducted *in situ* measurements of primary productivity (PP) using stable ^{13}C tracer method under different strength sites of SGD at nearshore coasts in Beppu Bay and Otsuchi Bay during the summer in 2016. Considering the differences of light intensity and water temperature at each site, we have also incubated the bottles taken from each site under same conditions of light and water temperature on land. In both bays, significant positive relationships between *in situ* PP and *ex situ* PP ($r > 0.91$, $p < 0.01$) indicated that *in situ* PP would be controlled by nutrient availability. In Beppu Bay, i*n situ* PP and ^{222}Rn activity ranged from 4.4 to 23.3 $\mu g\ C\ L^{-1}\ h^{-1}$ and 69.8 to 586.8 Bq m^{-3}, respectively. Although there was no clear relationship between *in situ* PP and ^{222}Rn activity, biomass specific PP (P_B, $\mu g\ C\ \mu g\ chl\ a^{-1}\ h^{-1}$) showed the positive correlation with ^{222}Rn activity. In Otsuchi Bay, i*n situ* PP and ^{222}Rn activity ranged from 4.5 to 10.7 $\mu g\ C\ L^{-1}\ h^{-1}$ and 298 to 765.8 Bq m^{-3}, respectively. ^{222}Rn activity did not related to *in situ* PP and P_B. This could be due to low phosphate concentrations in terrestrial confined groundwater. Our experimental studies suggested that the mechanism by which SGD affects phytoplankton production differs from one ecosystem to another.

Keywords: Primary productivity, 222Rn, Submarine groundwater discharge, Nearshore coast

Evaluation of the environmental condition of Submarine Groundwater Discharge (SGD) by using carbon stable isotope ratio recorded in the shell of sessile bivalve

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Submarine Groundwater Discharge (SGD) is often characterized by high concentration of nutrients and documented as an important pathway between land and sea contributing to the biological productivity in coastal waters. In the present study we investigated two subjects 1)whether the $\delta^{13}C$ of ambient water reflect the proportion of fresh water flux in SGD, 2)whether the $\delta^{13}C$ recorded in the shell of the sessile bibalve reflect the that of the ambient water. The SGD flux and the proportion of fresh water flux in SGD were measured by the seepage meter at Kamaiso beach along the Mt. Chokai volcanic coast in June and September 2016.The rock-oyster (*Crossostrea nippona*) was also sampled at Kamaiso Beach and adjacent 3 areas (Mega, Takinoura, Torisaki). There was a positive significant relationship between salinity and the δ 13C of ambient water ($p<0.01$). The $\delta^{13}C$ of the rock-oyster shell was high where the SGD flow rate was high and the positive significant correlation was found between the $\delta^{13}C$ of the rock-oyster shell and that of ambient water. In order to estimate the proportion of fresh water flux in SGD from the $\delta^{13}C$ of the rock-oyster shell, we used the two end member mixing equation including DIC concentration of both sea water and underground water. The average proportion of fresh water flux in SGD estimated from the mixing model ranged from 4 % (Torisaki) to 35 % (Mega). These values are higher than those estimated from the $\delta^{13}C$ of ambient water (1.3 % Torisaki and 18.1 % Mega). The difference of these results are seems to be the difference of local SGD environment around rock-oyster.

Keywords: Submarine groundwater discharge, sessile bivalve, Rock-oyster, carbon stable isotope ratio, SGD flow rate, the proportion of fresh water flux in SGD

Numerical analysis of the ecosystem responses to the changes of nutrient supply in the Western Seto Inland Sea, Japan

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The Seto Inland Sea is a representative coastal sea in Japan, and the nutrients in this region are mainly contributed by the following three nutrient sources; river, sediment, and open ocean. The nutrient supplies from the river and sediment have been reduced through the efforts for environmental cleanup over the last several decades. As a result of such excessive environmental cleanup, oligotrophic condition frequently occurred in this region in recent years. On the other hand, the nutrient supply from the open ocean associated with the oceanic water intrusions is rich in its variations because the oceanic water intrusions are closely associated with the current speed and position of Kuroshio Current south of Japan. In this study, we investigated the responses of the lower-trophic level ecosystem in the Western Seto Inland Sea to the variations of the above three nutrient supply amounts using an ecosystem model. Sensitivity analysis showed that the nutrient supply amount from the open ocean has much larger impact on the ecosystem than the nutrient supply amounts from the river and sediment. Large phytoplankton (diatom) and mesozooplankton (copepod) are dominant in the plankton assemblage in this region and they are highly sensitive to the variations of the nutrient supply amount.

Keywords: ecosystem model, nutrient, oceanic water intrusion, oligotrophic condition

Effects of submarine groundwater on growth of fishes: a cage experiment for flatfish juveniles

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In order to detect the possible effects of submarine groundwater discharge (SGD) on fish growth, a cage experiment were conducted in coastal waters of central Seto Inland Sea, Japan. Growth of juveniles of marbled sole, a flatfish species, temperature, prey availability in water and stomach contents of the juveniles were compared between sites with high and low SGDs monitored by the use of radon concentration. Juvenile growth rate, prey availability, stomach content weight per fish were higher at the site with high SGD while temperature did not differ between the two sites. The SGD was suggested to promote growth and feeding the juveniles in the tidal flat.

Keywords: water-food NEXUS, Fishery resources, submarine ground water, flatfish, feeding, growth

