Summary of investigation for submarine groundwater discharge in Suruga Bay

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Submarine groundwater discharge (SGD) in coastal area has been recognized as an important pathway from land to ocean. Suruga Bay is adjacent to the foot of Mt. Fuji where active groundwater flow system exist, and it could be occurred that large amount of groundwater directly discharges into the bay.

To evaluate SGD and groundwater flow system in the coastal area of Suruga Bay, some geophysical and geochemical surveys have been conducted from 2013 to 2015. Side scan sonar and sub bottom profiler was used to detect an anomaly of sonic wave at the bottom of sea. Flow direction and velocity around the coast were observed by the Acoustic Doppler Current Profiler. Distribution of radon and salinity in surface water was investigated by towing survey. Bottom water of the bay was also collected by using the Niskin sampler and analyzed for radon. This study attempts to combine each survey result and summarize the investigation of submarine groundwater discharge in Suruga Bay.

Keywords: submarine groundwater discharge, Suruga Bay

Spatial distribution of oxygen and hydrogen isotope ratios of seawater in the nascent Kuroshio of Lamon Bay

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The vertical and horizontal variations of oxygen ($\delta^{18}O$) and hydrogen ($\delta^{2}H$) isotopic composition of seawater were investigated in Lamon Bay and offshore waters, east of Luzon Island (14°-19°N, 122°-126°E; Fig. 1a) during a research cruise of the R/V Roger Revelle in April/May 2012. The $\delta^{18}O$ increased with depth from the surface, reaching a maximum of +1.5‰ to +2.0‰ at the salinity maximum of North Pacific Tropical Water between 100 m and 200 m. Then, the $\delta^{18}O$ decreased toward the salinity minimum of North Pacific Intermediate Water near a depth of 500 m. Below this salinity minimum, the $\delta^{18}O$ remained within a narrow range between -1‰ and 0‰ to 4,000 m. The $\delta^{18}O$ of surface water showed a spatial gradient from the nearshore (southwest) area of the Bay (-0.3‰) to the offshore (northeast) waters (+0.6‰) and significantly correlated to the salinity ($p < 0.0001$; Fig. 1b), reflecting influence of freshwater input from the Island. By linear regression, the $\delta^{18}O$ of freshwaters supplied to Lamon Bay could be estimated to be around -5.3‰, which is consistent with the riverwater $\delta^{18}O$ found in the central Philippines. Variation of the $\delta^{2}H$ followed similar patterns as observed for $\delta^{18}O$, although relatively high $\delta^{2}H$ values compared to $\delta^{18}O$ were recorded in surface waters of nearshore area, reflecting the deuterium excess of freshwater supplied from the land. The $\delta^{18}O$ and the salinity were distinctly lower in the cyclonic dipole (see Gordon et al., 2014), corresponding to the part of Lamon Bay between the nascent Kuroshio and Luzon Island. The average pH in this area (8.114±0.007) was also significantly ($p < 0.003$) lower than the other parts of the observed area (8.125–8.134; Fig. 1c). This spatial trend implies that the extent of freshwater inflow including lowered pH on Lamon Bay and offshore waters is constrained by the flow path of the nascent Kuroshio and its feeder current. On the other hand, the average pH of the nascent Kuroshio was slightly higher than the feeder current and the anticyclonic dipole waters (8.134 vs. 8.126, $p = 0.0329$), which suggests unexplored biogeochemical process that keeps pH in the Kuroshio high relative to that of the freshwater input.

Keywords: oxygen isotope ratio of seawater, vertical structure, freshwater input, pH, Lamon Bay

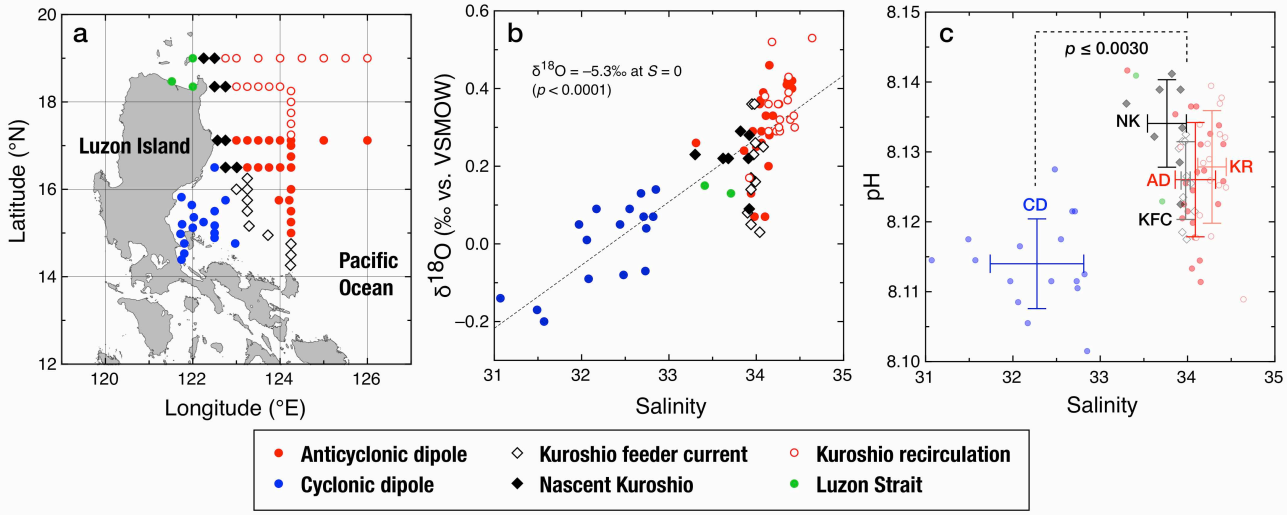

Fig. 1. Location of water sampling points (a), and plots of $\delta^{18}O$ (b) and pH (c) vs. salinity in surface seawater samples. Water areas are defined according to Gordon et al. (2014), doi:10.1002/2014JC009882.

Dynamics of dissolved inorganic nitrogen and phosphorous of the river water in the Kunisaki Peninsula in summer

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Kunisaki Peninsula Usa area in Oita Pref. was designated as GIAHS (Globally Important Agriculture Heritage Systems) in 2013. It has an abundant SATOYAMA represented by KUNUGI (Quercus acutissima) and a unique water use system connected by a number of small ponds. This unique water use system would affect river water quality in each watershed as well as estuarine and coastal biological production. However, its influence is still unclear. In this study, we assessed the effect of forest and water use system on nutrient concentrations in each river water and nutrient transport to coastal region.
Concentrations of DIN, DIP and d-excess of water isotopes ranged from 6.3 to 153.4 μM, from 0.1 to 4.1 μM and from 8.9 to 15.5, respectively. Fluxes of DIN and DIP from each watershed to coastal regions ranged from 0.8 to 140 kg d^{-1}, and from 0.2 to 22 kg d^{-1}, respectively. Although the fluxes were mainly dominated by river discharge, the molar ratio of DIN and DIP (DIN/DIP) varied from 6 to 39. We found positive exponential relationship between DIN/DIP and d-excess. These results suggests that unique water use system affected the difference in DIN and DIP dynamics within the watershed, since a number of ponds increased d-excess values from upstream to downstream. Moreover, in the Kunisaki Peninsula, the forest supplied DIN to the river, while DIP was mainly supplied from the agricultural land.
Therefore, higher d-excess and DIN/DIP showed lower retention time and larger impacts of forest. On the other hand, lower d-excess and DIN/DIP showed higher retention time and larger impacts of agricultural land.

Keywords: Nutrients, stream water, agricultural land, forest, GIAHS

A comparative study of in situ primary productivity under different sites of submarine groundwater discharge impacts in Japanese coasts

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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, very little is known about an exact relationship between input of groundwater and response of primary production. To clarify the relationship, we conducted in situ measurements of primary productivity using stable ^{13}C tracer method under different strength sites of SGD in the Japanese coasts (Site A: Obama Bay, Site B: Beppu Bay and Site C: the coastal area of Mt. Chokai) in summer from 2013 to 2015. Simultaneously, ^{222}Rn activity was measured as SGD index. ^{222}Rn activity in Site A, B and C varied from 0.8 to 6.0 dpm L^{-1}, 3.6 to 11.2 dpm L^{-1} and 0.4 to 444.5 dpm L^{-1}, respectively. In situ primary productivity in Site A, B and C ranged from 7.0 to 49.5 μg C L^{-1} h^{-1}, 10.7 to 38.4 μg C L^{-1} h^{-1} and 0.8 to 11.8 μg C L^{-1} h^{-1}, respectively. In site A, there was significant relationship between in situ primary productivity and ^{222}Rn activity. Although light intensity and water temperature were different in each station and month, concentrations of nutrients limited primary productivity. In site B and C, concentrations of dissolved inorganic nitrogen and phosphorus showed significant increasing trends with an increase of ^{222}Rn activity, indicating nutrients in coastal regions were mainly derived from the SGD. However, there were no clear relationships between in situ primary productivity and ^{222}Rn activity, since primary production would be limited by light intensity as well as nutrients. Our experimental studies clearly showed that nutrients through the SGD affect crucial impact on primary production in coastal ecosystems.

Keywords: Primary productivity, 222Rn, Submarine groundwater discharge, Coastal seas

Analysis of harmful phytoplanktons in Yodo River mouth by the numerical ecosystem model

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Red tide of Alexandrium tamarense occurred in Yodo River estuary in Japan in 2007, 2011 and 2013. A. tamarense is marine phytoplankton and causes shellfish poisoning. We had made in-situ observation on April 2-3, 2012, and analyzed the temporal variation of marine phytoplankton by using the numerical ecosystem model. CTD and ADCP observation and water sampling were carried out with the tidal change. Nutrient and Chl.a concentrations and the cell density of A. tamarense were analyzed. Seawater ran to upstream in the surface layer. And fresh water went to the sea in the bottom layer. It is the typical estuary circulation. The estuary which have 2800m in length was divided to three layers, 0-0.5m, 0.5-1.5m and 1.5m-bottom. The thickness of the bottom layer is changed with the tidal change. Nutrient, phytoplankton, the dissolved organic matter and the particulate mutter are in each layer, and the bio-chemical process, photosynthesis, mortality, decomposition and so on, were formulated. Diurnal migration, salt limitation and utilization of organic matter for the photosynthesis and mortality by low salinity were considered in the bio-chemical process of A. tamarense. Then the temporal variations of each morphology and A. tamarense were calculated. The variation of phytoplankton in each layer was almost reproduced in-situ data. Marine phytoplankton was not hardly produced in Yodo River estuary and was supplied from the ocean. Phytoplankton which cannot swim by oneself almost floated by the horizontal advection, it is the estuary circulation. But only 27% of A. tamarense transported from the ocean to the bottom layer go through upstream. 36% of it returned to the ocean in the middle and the surface layer, and other 36% died in the surface layer. Weak estuary circulation is effective to the transport limitation to the upper stream of tamarense in Yodo River estuary.

Keywords: Yodo River , harmful phytoplanktons , numerical ecosystem model

The inflow of hot spring heat impact on fish communities around estuaries in Beppu, Oita prefecture

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Hot spring drainage flows into a river and then flow into the coastal area in Beppu, Oita prefecture which is a region with many hot springs in Japan. In Hirata River where many hot spring drainage flow into, hot spring drainage creates a better habitat for *Oreochromis niloticus* (Nile tilapia), a foreign species, in terms of available food and water temperature. Hot spring drainage flow into the river except Hirata River in Beppu area. However, it is not clear that the influence of hot spring drainage on ecosystem of those rivers. In order to evaluate the impact of thermal energy from hot spring drainage on the fish communities near the estuary, we investigated water temperature, flow rate and fish communities near the estuaries of six rivers in Beppu area.
We sampled the fish using a small seine net in January 2015. Although the number of fish collected in four rivers was very small, Nile Tilapia and *Opsariichthys platypus* was collected in Hirata River and Haruki River, respectively. Hot spring drainage flow into these two rivers, however, there is a big difference in the water temperature near the river mouth in these two rivers. These results suggest the possibility that the difference in inflow of the hot spring heat affects the dominant species of the fish community near the estuary. In this presentation, we will discuss the inflow of hot spring heat impact on fish communities near the estuary with the result of the summer investigation.

Keywords: hot spring heat, fish community, around estuary, hot spring drainage

Comparative study of growth in Manila clam under different environmental conditions of submarine groundwater discharge

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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. We investigated to what extent SGD contributed to the growth of primary consumer by the field rearing experiments of Manila clam at two sites (Mega and Torisaki) along the Mt. Chokai volcanic coast in northern Japan from June to August 2015. Average Radon 222 (^{222}Rn) concentration at surface layer of Mega and Torisaki for two months were 4037 Bqm^{-3} and 241 Bqm^{-3}, respectively. The $\delta^{13}C$ of shell of Manila clam ($\delta^{13}C_{SHELL}$) reflected the $\delta^{13}C_{DIC}$ of the ambient water, i.e. lower $\delta^{13}C_{SHELL}$ value at Mega than that at Torisaki. There was the positive correlation between ^{222}Rn activity and DIN concentration ($r=0.881$ $p<0.01$). Contrary to expectations, the average growth rate of Manila clam reared at Mega was slightly smaller than that at Torisaki. The concentration of chlorophyll-a was almost the same at two sites. However water temperature at Mega was about 2 ℃ lower than Torisaki. Kobayashi and Toba (2005) reported that clear positive correlation between the growth rate of Mania clam and rearing water temperature. This suggested the negative effect of low temperature on the growth of manila clam. This study showed the seepage area does not always have a favorable influence on fisheries resources. The larger-scale effects of SGD on biological production of primary consumer is necessary.

Keywords: submarine groundwater discharge, Manila clam, growth , stable carbon isotope ratio

