Nutrient circulation and biological production from forests to coastal waters

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We studied the effects of land-use and human activities on the circulation of nutrients and biological production in rivers and coastal waters in three watersheds in Kyoto and Oita prefectures. In Kyoto's Yura River dissolved phosphorus, dissolved nitrogen and dissolved iron densities did not show a clear relationship with forested area, but had significant positive correlations with farm lands and urban areas.Phosphorus limited phytoplankton production in the river waters and nitrogen in coastal waters. Dissolved iron was not a limiting factor of primary production in river or coastal waters. With regards to carbon utilization, some macrobenthos with cellulase consumed terrestrial organic matter in downstream and shallow coastal areas. In addition, carbon stable isotope ratio ($\delta^{13}C$) analysis suggested that seabass juveniles that migrated into the downstream areas grew on a trophic chain connected to terrestrial plants. We compared Oita's Katsura River, with a high forested area, and the Iroha River with low forested area. Nutrients, biodiversity and biological productivity tended to be higher in the Katsura River than in the Iroha River. It is possible that nutrients are supplied by forests within the Katsura River system. These results suggest that the structure of ecological linkage from forests to coastal waters is different in each watershed system.

Keywords: nutrient circulation, biological production, watershed

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Variety of impacts of the freshwater-derived nutrients on the marine ecosystem

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The discharge of terrestrial freshwater and associated nutrients to coastal areas is considered to increase the growth of planktonic and benthic algae which in turn increases the biomass of filter feeders and the other fishery resources. However, species of the primary producers and their biomass that can receive the positive influence from the freshwater discharge are not consistent depending on many environmental factors: benthic substrate, residence time of the water mass, limiting nutrients, light intensity (turbidity), salinity and existence of dormant cyst etc. Furthermore, the impact from the increased phytoplankton will not be always positive. Some species enhance the growth rate of bivalves and zooplanktons as food sources, but the others damage the growth of the organisms severely by its toxins.
Rapidly grown phytoplankton during rainy season due to nutrient-rich freshwater could also contribute to the formation of the hypoxic water mass. Because organic matters derived from phytoplankton are generally labile components, they are accumulated and decomposed by bacteria under the thermocline in summer. Many studies suggest that the content of silica frustules, sulfur compounds such as dimethylsulfoniopropionate (DMSP) and other compounds varies depending on phytoplankton species and environmental conditions, which means that the decomposition rate and oxygen consumption rate in the water column should vary as well. Although this hypoxic water is known to cause mass mortality of benthic organisms, our recent studies suggest that the anaerobic autotrophic bacterial mat itself can be a potential food source for benthic filter feeders and the other organisms at a higher trophic level.
Therefore, to evaluate the impact of freshwater discharge on the fishery resources, it is important to consider various environmental changes and carefully monitor the marine environments in the long-term.

Keywords: Marine Ecosystem, Freshwater Input, Fishery Resources

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Water-energy-food nexus: Effects of groundwater use as heat energy on fishery resources in the coastal area

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Water, energy, and food are the most fundamental resources for human well being and a sustainable society. Demands for these resources are estimated to drastically increase in the near future because of increases in population and changes in lifestyle. These three resources have also been inter-related, and make a “nexus” which causes tradeoff between resources and conflict between stakeholders. In this study, the groundwater-energy-fishery nexus is analyzed and evaluated in the snowy area of Obama City, Fukui Prefecture, Japan. The objective of this study is to evaluate the effects of groundwater used as heat energy for the melting of snow accumulated on roads, on fishery productions in the coastal area. The submarine groundwater discharge which carries nutrients into the ocean is reduced by excess groundwater pumping for melting snow. Positive correlation has been found between primary production rates in Obama Bay and radon concentrations which show the magnitude of the submarine groundwater discharge. Therefore, the increase in groundwater pumping on land may reduce fishery productions in the ocean. Results of 3D numerical simulations of the basin scale groundwater model show a reduction of SGD by 5 percent due to an increase in groundwater pumping by 1.5 times. This reduction of SGD caused a 3.7 ton decrease in fishery production under the aforementioned assumptions. The groundwater-energy-fishery nexus was found in Obama Bay, Japan and the tradeoff between water and food was evaluated.

Keywords: Water-energy-food nexus, submarine groundwater discharge, land-ocean interaction

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

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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. 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 great 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), water quality analyses

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Estimation of submarine groundwater discharge and associated nutrient fluxes in Otsuchi Bay, northeast Japan in summer

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Otsuchi Bay is a small semi-enclosed bay along the Sanriku ria coast. Although the watershed of the bay has large amounts of groundwater resources, the rates of groundwater input into the bay and associated nutrient fluxes are still unclear. In this study, we estimated the rates of submarine groundwater discharge (SGD) and associated nutrient fluxes into Otsuchi Bay using the radon-222 (^{222}Rn) and salinity mass balance model during the spring and neap tides in summer. As a result, SGD rates ranged from 0.10 to 1.07×10^{6} m^{3} day^{-1} (1.29 to 13.16 cm day^{-1}) with a mean of 0.43×10^{6} m^{3} day^{-1} (5.28 cm day^{-1}) during the four sampling periods. This value was similar to the annual groundwater recharge rate (0.63×10^{6} m^{3} day^{-1}) estimated by the water balance method in the whole basin. Estimated fluxes of dissolved inorganic nitrogen (DIN) and phosphorous (DIP) through the SGD were 50.2 to 511.6 kg day^{-1} and 0.4 to 4.2 kg day^{-1}, respectively. In contrast, these fluxes through the river water were 127.9 to 336.6 kg day^{-1}, 1.7 to 7.8 kg day^{-1}, respectively. Nutrient fluxes through the SGD were approximately 40 and 33 % of all terrestrial fluxes of DIN and DIP, respectively. In addition, DIN flux of the SGD was approximately 7.7 % of that of the oceanic water even though DIP flux of SGD was only 0.2 %. In Otsuchi Bay, the N/P ratio in bay water during the stratified period was often lower than Redfield ratio. Therefore, DIN supply from the SGD would have a non-negligible contribution on primary production during the stratified period.

Keywords: submarine groundwater discharge , Otsuchi Bay

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Ongoing stress of transboundary air pollution: Assessment of effects of increasing nitrogen loading from the watershed on coastal ecosystem in Wakasa Bay

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Anthropogenic emissions of reactive nitrogen (N) due to fossil fuel combustion and modern agriculture practices have dramatically increased in global scale. In the Japanese watershed along the Sea of Japan, large amounts of reactive N emitted from northeastern Asia have deposited onto forest ecosystems, and thus N concentrations in river and groundwater have been increased year to year. Remotely modified N concentrations of terrestrial waters in local watersheds would affect coastal ecosystems. However, influence of N export from the watershed along the Sea of Japan on coastal ecosystem is still unclear. In this study, we assessed the effect of increasing nitrogen loadings from the watershed on coastal ecosystem in Obama Bay using the sediment cores. Mean sedimentation rates estimated from $^{210}Pb_{ex}$ within the bay increased from 0.13 g cm^{-2} yr^{-1} in 1960-1980 to 0.55 g cm^{-2} yr^{-1} in 2000-2015. Corresponding to long-term increase of N concentrations in the rivers, nitrogen contents of the sediment cores that were mainly composed of marine autochthonous organic matter have also increased year to year. These results suggested that an increase of nitrogen loading from the watershed would promote production rates of autochthonous particulate organic materials. In addition to N-limited condition of the past, a drastic decrease of seagrass and seaweed might facilitate remarkable increase of sedimentation rates and nitrogen content.

Keywords: sedimentation rate, eutrophication, nitrogen deposition, Sea of Japan

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Long term variation in dissolved oxygen and COD budgets in the inner area of Ariake Sea in summer

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[Introduction]
In the inner area of Ariake Sea, the hypoxia occurs every summer now. Since it induced massive kills of bivalves, it became a big problem. The increase in oxygen consumption by organic matter decomposition is one the potential mechanisms for the long term increase in hypoxia. In the inner area of Ariake Sea, the monitoring of the Chemical Oxygen Demand (COD) in water has been carried out for the index of the concentration of the organic matter. Therefore, in order to clarify the long term variation in the bottom DO in summer and to understand the mechanism of the variation, we made data analysis.
[Data and methods]
The data we used are the monthly monitoring data taken by the Saga Prefectural Ariake Fisheries Research and Development Center and the Fukuoka Fisheries and Marine Technology Research Center Ariake-Sea Laboratory from 1972 to 2014. And also, the river discharge and riverine input of COD through the 4 class A rivers (Chikugo, Yabe, Kase and Rokkaku River) flow into the inner area of Ariake Sea were used. As the river discharge and COD loads, the dataset by Tezuka et al (2013) and supplement until 2014 were used. The bottom DO in the inner area of Ariake Sea in summer fluctuates largely affected by the variation in stratification caused by the river discharge. Therefore, In order to remove the effect of the variation in stratification, we calculated the potential of hypoxia DO_s using the method by Hayami et al (2006). In order to understand the mechanism of the long time variation in COD, we made a box model analysis of COD for the inner part of the Saga and Fukuoka waters (Fig.1). We calculated the average salinity in the box 1 and 2 during 11 consecutive years. Using these salinities and river discharge, the salinity budget for the box 1 was calculated to get the water exchange flux between the box 1 and 2 (q). Using q, river discharge, riverine input of COD and the average COD in the box 1 and 2 during 11 consecutive years, we calculated the COD budget for the box 1. From this calculation, we got the internal production of COD in the box 1. It is the balance between the organic matter production by algae and the consumption of organic matter by grazers.
[Results and discussions]
The DO_s in the Saga water in July decreased from 1970s to early 90s then recovered slightly (Fig.2). The COD in the bottom water in July increased from 70s to early 90s then decreased slightly (Fig.2). There was a strong negative correlation between DO_s and 11 year running mean of the bottom COD (R=-0.94).
The COD in the box 1 in July and August increased from 80s to early 90s (Fig.3). There are 4 potential reasons for this increase, 1) the increase in the initial value (COD in June), 2) the increase in internal production, 3) the decrease in the fluxes by advection and water exchange and 4) the increase in riverine input. The flux by water exchange decreased and the advective flux and riverine input remained almost in the same level (Fig.4). The initial value increased from 1986 to 1988 but then decreased. On the other hand, the internal production increased. It means that the organic matter production in the sea increased or the consumers of the organic matter (grazers) decreased. In the same period, the catch of bivalves in Saga and Fukuoka prefectures decreased. Moreover, there were oyster reefs of the area of 546 ha, but it decreased to 161 ha now (Fisheries Agency, 2011). These facts indicate that the decrease in grazers actually occurred. The increase in

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COD without the increase in terrestrial input suggests that such increase in COD was due to the organic matter production in the sea. Moreover, these results suggest the negative feedback control that the decrease in bivalve lead the increase of phytoplankton and it lead the increase of organic matter in the bottom water to decline the bottom DO with the decrease of the benthos.

Keywords: long term variation, dissolved oxygen, chemical oxygen demand, box model, Ariake Sea

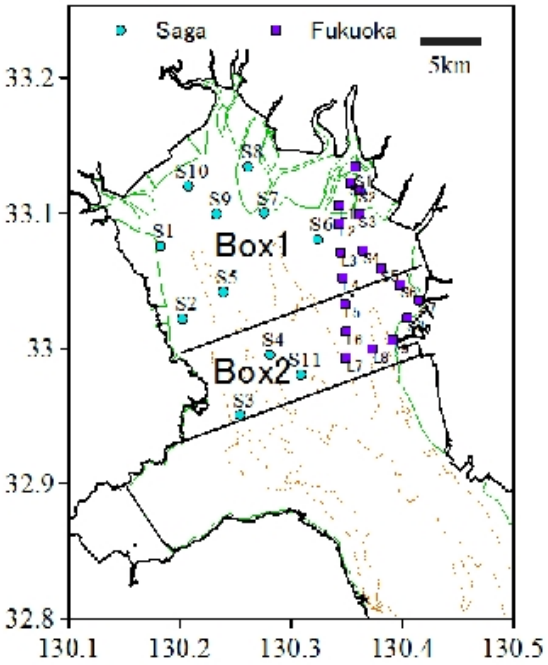

Fig.1 Map of the inner area of the Ariake Sea and location of the observation stations.

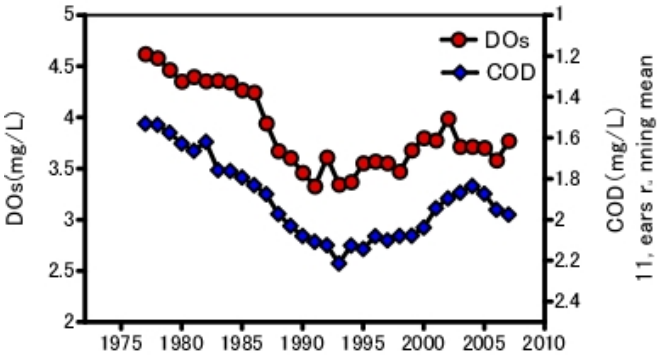

Fig.2 Variations in DO_s and COD (11 years running mean) in the bottom layer in Saga water in July.

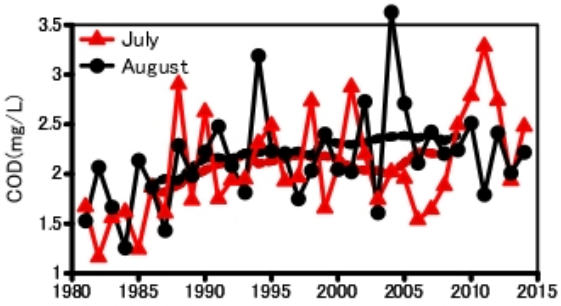

Fig.3 Variation in COD in Box1 in summer. Brocken lines are 11 years running mean.

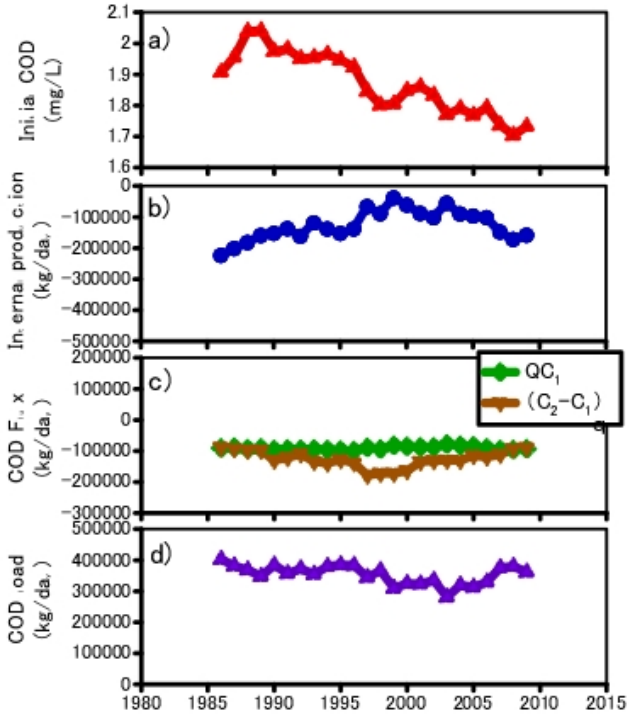

Fig.4 Variations in a) initial COD, b) internal production of COD, c) COD flux by advection and water exchange between box1 and box2 and COD load from rivers.

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Stable isotope analysis of surf clam *(Pseudocardium sachalinense)* in Hamanaka Town, Hokkaido, and the connection between Kiritappu Wetland and coastal waters

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The suspension-feeding benthos surf clam *Pseudocardium sachalinense*, living on phytoplankton, benthic microalgae and detritus, is one of the most important marine products in Hamanaka Town, Hokkaido. We measured stable carbon and nitrogen isotope ratios ($\delta^{13}C$ and $\delta^{15}N$) and carbon-nitrogen (C/N) ratios of surf clam (adductor muscle and stomach contents), oceanic particulate organic matters (POM), oceanic sediments, riverine POM and soil as well as physical and chemical parameters such as temperature and salinity, chlorophyll-a and nutrients in April through September, 2015 in coastal areas in Hamanaka Town, Hokkaido. We also examined the food sources that support surf clam, the possible connection between wetland and coastal waters, and also spatial and seasonal variation. Additionally, taste comparing and free amino acid analysis were conducted for further investigating taste differences of surf clam in different fishing areas. The results show that taste of surf clam was different among fishing areas, which might be caused by the difference in free amino acid content. Our results also show that the isotope and C/N values of surf clam and oceanic organic matters were significantly different from those of riverine organic matters, and that there was no significant difference among the fishing areas. This means that land-derived organic matter is not direct food source of surf clam and land-derived organic matter does not affect the coastal environment. Also, benthic microalgae and epiphytes are considered to be the major food sources of surf clam in all sampling seasons since they have close isotope and C/N values to surf clam. The overall results imply that excess inflow of land-derived organic matter may harm surf clam and the coastal environment, suggesting the importance of the importance of the role of the wetland and the conservation.

Keywords: surf clam, carbon, nitrogen, isotope, organic matter, wetland

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Analysis of the coastal food web and influence of terrestrial input in Toyama Bay using δ ^{13}C and $\delta^{15}N$

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Toyama Bay is a semi-enclosed bay facing the Sea of Japan, which has a distinctive coastal environment. It receives a large amount of freshwater (such as river and submarine groundwater discharge (SGD)) and it is also affected by the Japan Sea water. In this study, to evaluate terrestrial effect on coastal organisms in Toyama Bay, we analyzed food web structure and estimate utilization situation of organic matter and nutrient (NO_3^-) derived from land in food web using stable isotope ratios ($\delta^{13}C \cdot \delta^{15}N$; $\delta^{15}N \cdot \delta^{18}O$ in nitrate).

The $\delta^{13}C$ values of consumers (such as bivalve, crustacea and fish) in the coastal area of Toyama Bay were clearly higher than those in the riverine particulate organic matter (POM). This indicates that consumers do not use terrestrial organic matter as their carbon source. The calculated contribution of benthic microalgae to diet of consumers was about 30 - 60 %, suggesting that ^{13}C-enriched benthic microalgae is an important carbon source for the coastal food web in Toyama Bay. Primary producer in coastal area of Toyama Bay shows much lower $\delta^{15}N$ values than typical primary producer in other coastal area. In addition, $\delta^{15}N$ (NO_3^-) values of coastal area in Toyama Bay are also lower than the $\delta^{15}N$ (NO_3^-) values of deep seawater of Toyama Bay and Japan Sea water. Low $\delta^{15}N$ (NO_3^-) values were also observed in the rivers and SGD around Toyama Bay. Our results suggest that coastal organisms in Toyama Bay are influenced by terrestrial input of low $\delta^{15}N$ (NO_3^-) through the rivers and SGD.

Keywords: Toyama Bay, Carbon and Nitrogen stable isotope ratio, Food web

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Numerical Simulation of the relationship between water quality and the catch of sand-eel in Set-Inlad-Sea

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In Seto-Inland-Sea, the catch decrease of sand-eel is viewed with suspicion.
In Harima-Nada, there is relationships between water quality (DIN) and the cath of sand-eel.
It is considered there are some any relationships between nutrient load from a continental area and fish catchs.
Here, material cycle of nutrints, phytoplankton, zooplankton and sand-eel were calucurated by used of the numerical simulation model.

Keywords: ecosystem model, Osaka-Bay, Ammodytes personatus, Plankton -eating fish, nutrient reduction

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Possible effects of the global warming on fish species diversity and production through submarine groundwater in coastal areas

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In order to forecast possible effects of the global warming on fish species diversity and production through changes in submarine groundwater discharge, physical and biological surveys were conducted at three sites in Japan (Yuza, Yamagata Pref., Obama, Fukui Pref., Takehara, Hiroshima Pref.), where submarine groundwater discharge has been observed.. Number of fish species, fish abundance and biomass were compared between areas of different levels of Radon concentration at each site. Contribution of nutritional matters of terrestrial origin through submarine groundwater was evaluated by analyses of stomach contents and stable isotopes of fishes.

Keywords: submarine groundwater, fish, distribution, species diversity, biomass, wood web

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