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Effects of light, temperature and ground water level on the CO_2 flux of the sediment in the high water temperature seasons at the artificial north salt marsh of Osaka Nanko bird sanctuary, Japan

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ABSTRACT

Field investigations and indoor experiment were carried out to clarify the effect of temperature and chlorophyll a concentration of the sediment, photon flux density, and ground water level on the absorption and emission of CO_2 from the surface sediment of the artificial salt marsh. The flux of CO_2 absorption was closely related to sediment temperature, chlorophyll a and photon flux density. On the other hand, flux of CO_2 emission changed depending on the sediment temperature and ground water level. The ground water level was thought to be indispensable for estimating CO_2 emission from the sediment of the intertidal zone of the salt marsh. Using equations of CO_2 flux with sediment temperature, chlorophyll a, photon flux density and ground water level, the total CO_2 absorption and emission of the artificial north salt marsh of Osaka Nanko bird sanctuary was estimated as ca. 23 tons (4.3 g CO_2 m^{-2} day^{-1}) for absorption and ca.14 tons (2.6 g CO_2 m^{-2} day^{-1}) for emission in May to September 2014. These results suggest that a net of 9 tons of CO_2 (1.7 g CO_2 m^{-2} day^{-1}) was absorbed, and that this salt marsh performs the function of a CO_2 sink in high temperature seasons.

1. Introduction

The benefits obtained from natural environments are referred to as ecosystem service. The economic value of the ecosystem services was examined and estimated as $15–54 \times 10^{12}$ US$ (Costanza et al., 1997), which is generally divided into supporting services, provisioning services, regulating services and cultural services. In terms of the regulating services, IPCC (2013) reported that a $555 \pm 85 \times 10^{15}$ g of carbon was released to the atmosphere through fossil fuel combustion, cement production, and change of land use due to deforestation from 1750 to 2011. However, more than half of the carbon emitted to the atmosphere was inferred to be absorbed by biological activities. The ability of marine plants, including phytoplankton, benthic microalgae and seaweeds, to act as a CO_2 sink, so called 'Blue Carbon' (Wada, 2012), has recently been subjected to great interest.

Nellemann et al. (2009) reported that 1) over half the biological carbon in the world is captured by marine-living organisms, 2) the total area of mangrove, salt marsh and seaweed forest occupies less than 0.5% of the whole sea bed, and their plant biomass accounts for only 0.05% of the world, 3) 50–71% of the carbon storage in ocean sediments is conducted in mangrove, salt marsh and seaweed forest, 4) the potential for carbon storage in these habitats would be equivalent to at least 10% of the reductions by human beings required for maintaining CO_2 concentration in the air below 450 ppm.

In the Seto Inland Sea, a major temperate inland sea of western Japan, as many as 13247 ha of natural intertidal flats disappeared from 1898 to 2006 (Ministry of Environment, Japan, 2016) due to land reclamation for urban development, factory construction and agriculture. To compensate for the loss of these natural resources, artificial salt marshes or intertidal flats were constructed along the coast of the Seto Inland Sea, especially in the vicinity of urban areas. These were intended to restore the functions of water purification, biological diversity, nursery grounds for juvenile organisms, and to serve as amenity spaces for citizens. Following on the decrease in number of salt marshes and intertidal flats along the coast of Japan, some investigations have been carried out to clarify the biological production and purification potential of the salt marsh and/or intertidal flat (Kuwae et al., 1998; Nakamura and Kerciku, 2000; Kohata et al., 2003; Yamochi, 2008; Kokubu and Matuda, 2013). However, there is so far little information or knowledge on the

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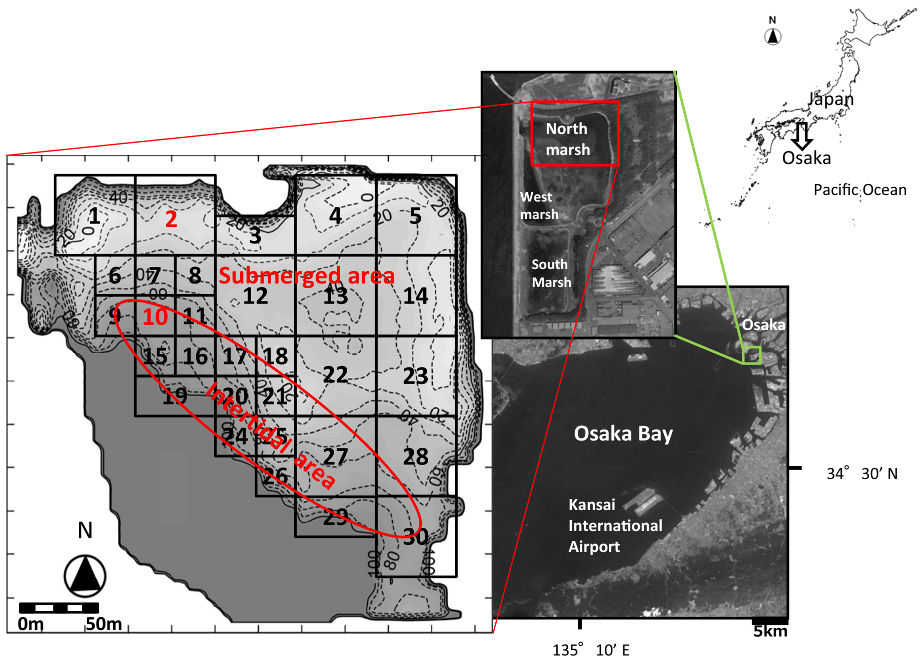

Fig. 1. Map showing the sampling areas (No. 1–30) at the north salt marsh of Osaka Nanko bird sanctuary, northeastern cost of Osaka Bay, Japan.

dynamics of CO_2 absorption and emission of the salt marsh and intertidal flat, especially of artificial ones, even though they are an important academic issue.

In the present research, CO_2 absorption and emission from the surface sediment, along with chlorophyll a, ground water level, temperature, and photon flux density were measured at an artificial salt marsh in the high water temperature seasons (May to September) of 2012–2014, and effects of environmental factors on the dynamics of CO_2 absorption and emission from the surface sediment are discussed.

2. Materials and methods

2.1. Field survey at the Osaka Nanko bird sanctuary

2.1.1. Study site

Osaka Nanko bird sanctuary was constructed in 1983 at the north-western part of Sakishima District, Osaka Port, Japan (Fig. 1). This lagoon-type artificial bird sanctuary is composed of a north salt marsh (4.6 ha), south salt marsh (3.8 ha), west pond (1.4 ha) and reed fields. The surveys were conducted at the north salt marsh, which was constructed by capping with sand over dredged sediment. Six sluice pipes (74 cm in diameter) were installed through the seawall in 1995, and the ground level at the bottom tip of the sluice pipe is L.W.L (Low Water Level) + 0.20 m, which enables seawater to flow in or out to Osaka Bay by way of tidal exchange. The averaged ground level of the north salt marsh is L.W.L. + 0.72 m, and its bottom almost entirely emerges at spring tide low water. The averaged exposure rate to air in areas of the north salt marsh is 17.3%, with a 1.0–1.2 mm median diameter of the surface sediment. Sand (0.064–2 mm in grain size) is dominant and its content showed a range of 45.4–74.1%. In contrast, silt and clay content (less than 0.064 mm in grain size) of the sediment was only 2.0–7.5%. Concentrations of carbon and nitrogen of the surface sediment occasionally increased with increasing detritus originated from benthic microalgae and decomposed seaweeds (*Ulva* spp. and *Gracilaria* sp.), varying between 1.6–12.4 mg C g dry sediment^{-1} and between 0.3–3.0 mg N g dry sediment^{-1}, respectively (Table 1).

Table 1
Profile of the north salt marsh of Osaka Nanko bird sanctuary.

Salt marsh	
Area (m^2)	46000
Average ground level (m)	L.W.L.* + 0.72
Average exposure rate to air (%)	17.3
Median diameter of the sediment (mm)**	1.0–1.2
Sand content (%)**	45.4–74.1
Silt and clay content (%)**	2.0–7.5
Concentration of carbon (mgC g dry sediment^{-1})**	1.6–12.4
Concentration of nitrogen (mgN g dry sediment^{-1})**	0.3–3.0
Sluice pipe	
Date of construction	Oct. 1995
Number	6
Diameter (cm)	74
Bottom tip of the pipe (m)	L.W.L. + 0.20

*L.W.L.: Low Water Level.
**Median diameter, sand, silt and clay contents are shown as values of 0–5 cm layer from the surface of the sediment. Carbon and nitrogen concentarations are values of 0–1.0 cm layer from the surface of the sediment.

2.1.2. Sampling and measurements

Thirty survey areas (12 areas: 50 m × 50 m, 3 areas: 50 m × 25 m, 15 areas: 25 m × 25 m) were designated in the north salt marsh, and CO_2 absorption, emission, temperature, and chlorophyll a concentration of the sediment, as well as with photon flux density and ground water level, were measured at a station of area 10 (as a representative of the intertidal zone) on May 23, June 6, July 4, August 29 and September 26 in 2012, May 22, July 24 and September18 in 2013, May 14, July 9, August 6 and September 10 in 2014. At a station of area 2 which represents the submerged zone of the north salt marsh, CO_2 absorption, emission, temperature, chlorophyll a concentration of the sediment and photon flux density were also measured on May 22 and July 24 in 2013, May 14, July 9, July 30, August 6 and September 10 in 2014.

A light and dark chamber method (Fig. 2) was employed for estimating the amount of CO_2 absorption or emission at the intertidal station of area 10. Base area and volume of the chambers were 1486 cm^2 and 31.7 L for the light chamber, 1385 cm^2 and 30.1 L for