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Impact of flood events on macrobenthic community structure on an intertidal flat developing in the Ohta River Estuary

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ABSTRACT

We investigated the effects of river floods on the macrobenthic community of the intertidal flat in the Ohta River Estuary, Japan, from 2005 to 2010. Sediment erosion by flood events ranged from about 2–3 cm to 12 cm, and the salinity dropped to 0‰ even during low-intensity flood events. Cluster analysis of the macrobenthic population showed that the community structure was controlled by the physical disturbance, decreased salinity, or both. The opportunistic polychaete *Capitella* sp. was the most dominant species in all clusters, and populations of the long-lived polychaete *Ceratonereis erythraeensis* increased in years with stable flow and almost disappeared in years with intense flooding. The bivalve *Musculista senhousia* was also an important opportunistic species that formed mats in summer of the stable years and influenced the structure of the macrobenthic community. Our results demonstrate the substantial effects of flood events on the macrobenthic community structure.

1. Introduction

Macrobenthic communities on intertidal flats are exposed to a wide range of human-mediated and natural disturbances that affect both population size and biomass (Pickett and White, 1985; Dolbeth, 2007; Whomersley et al., 2010; Baeta et al., 2011). Physical forcings control intertidal-flat hydrodynamics and consist of (1) tides, (2) wind-induced circulation, (3) waves, (4) density-driven circulation, and (5) the drainage process (Le Hir et al., 2000). These forcings affect the benthic communities through daily and seasonal changes in physico-chemical conditions on the intertidal flat (Chainho et al., 2007). In addition to daily and seasonal variations in these forcings, disturbances from episodic events such as storms are also important, and these events sometimes give dramatic damage to benthic communities. Waves associated with strong storm winds create major disturbances on intertidal flats located along open coasts (Kim, 2003). On the Daeho marcotidal flat in Korea, winter storms driven by a severe monsoonal climate resulted in the erosion of fine-grained surficial sediments (Lee et al., 1999).

Salinity stress is one of the factors important for determining macrobenthic community structure. The spatial heterogeneity of macrobenthos along estuarine gradients has been described in relation to salinity and sediment composition (Holland et al., 1987; Mannino and Montagna, 1997; Ysebaert et al., 2003). Constant low salinity without drastic change creates habitats favorable to mesohaline species. Freshwater input brings not only lower salinity but also nutrient enrichment, resulting in a macrobenthic community different from that under high salinity conditions. The pattern of declining species richness and diversity with decreasing salinity has been reported in most estuaries (Ysebaert et al., 2003; Lucero et al., 2006). In addition to the normal estuarine salinity gradient, flood and drought conditions can temporarily change salinities and create salinity stress for macrobenthic species (Eyre and Ferguson, 2006; Matthews, 2006; Cardoso et al., 2008; MacKay et al., 2010; Grilo et al., 2011). Ritter et al. (2005) reported that frequent salinity stress hindered the formation of a stable climax community. Salinity stress is an especially important disturbance for macrobenthic communities on the intertidal flats developing around river mouths that are periodically exposed to salinity stress along with the erosion of sediment and change of sediment composition produced by flood events (Salen-Picard et al., 2003; Cardoso et al., 2008).

The Ohta River diversion channel flowing into the Hiroshima Bay, Japan, is an artificial channel constructed for the rapid discharge of flood water and is characterized by the periodic

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intrusion of salt wedges (Kawanisi et al., 2010). Intertidal flats have formed in the lower intertidal zone. As intended, the flow condition in the channel drastically changes during flood events. The discharge under normal conditions is only 10–20% of the total flow of the Ohta River. However, during flood events about half of the total discharge passes through the diversion channel. The depth of water in the diversion channel at the Gion Bridge is normally less than 1 m and was as high as 8.01 m during the river flood events of 2004–2010 (Ministry of Land, Infrastructure, Transport and Tourism, 2012). These floods can result in moderate or catastrophic natural disturbances of the intertidal flat ecosystem through sediment erosion or deposition (Norkko et al., 2002; Smith et al., 2003) and exposure to low- or zero-salinity water (Chaparro et al., 2008; Becker et al., 2010). In this study, we investigated the effects of river floodings on the macrobenthic community on the intertidal flat developing in the Ohta River diversion channel.

2. Materials and methods

2.1. Study site

The Ohta River bifurcates into two main branches about 9 km upstream from its mouth (Fig. 1). The freshwater runoff into the diversion channel is usually controlled by the array of Gion sluice gates, located near the point of bifurcation. Normally only one sluice gate is slightly open in order to maintain the minimum flow in the diversion channel, and the inflow is about 10–20% of the total flow of the Ohta River. However, the exact discharge at the Gion sluice gates is unknown because the flow is influenced by tidal oscillation and saltwater intrusion. During flood events, all sluice gates are opened completely and the freshwater inflow through the Gion sluice gates into the diversion channel is designed to be about half the total river discharge. Because the flow at the Yaguchi gauging station, which is located 14 km upstream from the river mouth, is not affected by tide, the determination to open all Gion sluice gates is based on the depth of water, exceeding 2.1 m at the Yaguchi gauging station.

The river bed at the Yaguchi gauging station is Tokyo Peil (T.P.) +4.5 m. Our study site in the diversion channel is located 1.5 km upstream from the river mouth where the channel is 350 m wide. We monitored a point on the intertidal flat at the study site between 50 and 60 m from the right bank, in the lower intertidal zone (T.P. −1.2 m; Fig. 2). Kusatsu Harbor (T.P. ±0.0 m) is located near the study site (Fig. 1) and is used as a reference site to know fluctuation in tide level (Ministry of Land, Infrastructure, Transport and Tourism, 2012).

2.2. Field survey and on-site monitoring

During the period from 2004 to 2010, there were 23 flood events during which all sluice gates at Gion were completely opened (Table 1). Water depth data for the Gion sluice gates was obtained from the Water Information System (Ministry of Land, Infrastructure, Transport and Tourism, 2012).

Sediment dynamics were directly measured in 2006 by using a photoelectric sand surface profiler (SPM-VII, Sanyo-Sokki Instrument corp., Hiroshima, Japan). Salinity was monitored 5 cm above the sediment in 2010 using a water quality analyzer (WQC-24, DKK-TOA corp., Tokyo, Japan).

2.3. Sample collection and analysis

Field samples were collected every 1 or 2 months during low tide from April 2005 to November 2010. Three sediment samples were collected for macrofauna density and biomass determination from randomly selected locations using a box corer (25 cm × 25 cm; surface area 625 cm^2) to a depth of 25 cm. The sediment samples were wet-sieved in the field through a 1.0-mm mesh for 5-cm depth intervals to determine the vertical distribution of the macrobenthos. Macrobenthos retained on the mesh were preserved in 10% buffered formalin in water from the Ohta River Estuary. In the laboratory, macrobenthos were classified into species or the lowest taxon possible based on microscopic observation.

Three sediment cores were collected from random locations to a depth of 25 cm for sediment analysis using a cylindrical corer (65 mm; surface area, 33 cm^2). The physico-chemical characteristics of the sediments were evaluated in terms of grain-size distribution, silt and clay content, and ignition loss. The grain-size distributions were determined according to the Japanese Industrial Standard (JIS) test method for particle-size distribution of soils (Method A 1204; JIS, 2000). Briefly, the sediments were desalted and then treated with a 6% hydrogen peroxide solution to degrade

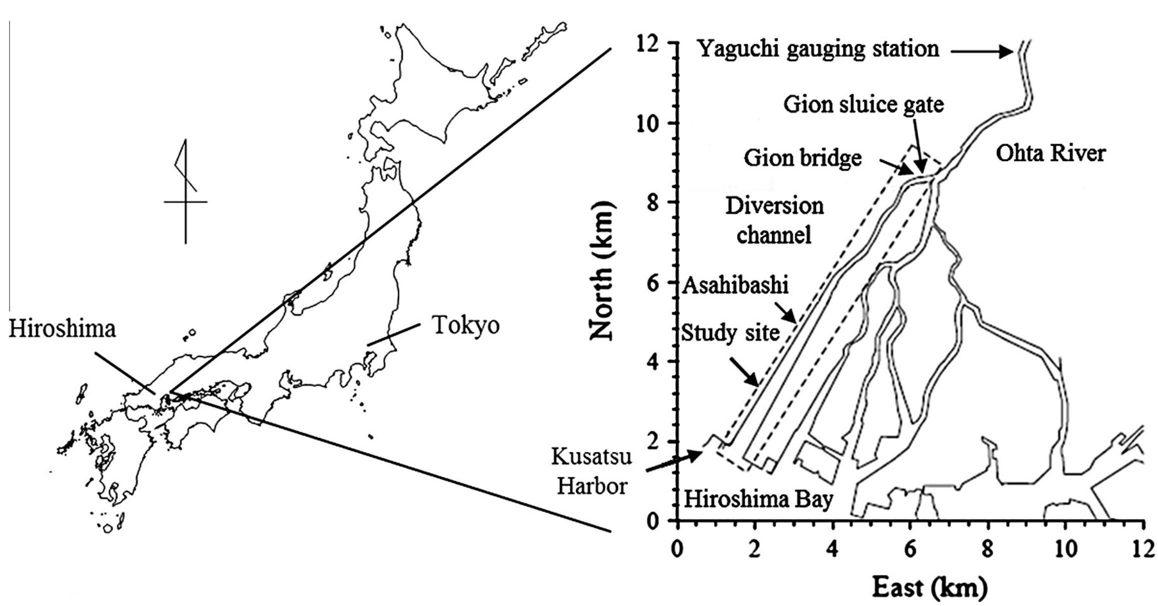

Fig. 1. Location of the study site in the diversion channel of the Ohta River, Hiroshima, Japan.