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Long term variation in transparency in the inner area of Ariake Sea

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ABSTRACT

This study analyzed the long time record of transparency (Secchi disk depth) in the inner area of Ariake Sea and determined the reason for the change. The data observed by the Saga Prefectural Ariake Fisheries Research and Development Center for 38 years at 10 or 11 stations was used. The Secchi disk depth increased significantly in autumn and winter. The analysis based on the 1 dimensional model of surface salinity and the SS concentration showed that the increase in Secchi disk depth would be caused by the decline of the SS supply at the source. It also suggested that there would have been an additional SS source existed in the bay head before 1984. It is coincident with the construction of the Chikugo Ozeki weir and the channel bed dredging. The channel bed depth of the Chikugo River estuary increased largely from 60's to 80's by dredging and became almost stable after 1985. Provided that the Chikugo River estuary was an additional SS source, the decline of the SS supply would be generated by the upstream displacement of the turbidity maximum induced by the increase in channel bed depth.

1. Introduction

Water transparency is one of the important factors affecting coastal marine ecosystem. In many coastal waters, it is a measure of the phytoplankton density. And also in turbid waters by suspended sediments, variation in transparency often controls the primary production (e.g. Cloern, 1987). Transparency can be measured easily with a Secchi disk. So, there are long time records without change in equipment or method. Such records might reflect anthropogenic activities through modification of coastal topography, land use and so on (e.g. Borkman and Smayda, 1998). Therefore, we analyzed the historical record of Secchi disk depth in the inner area of Ariake Sea, Japan.

Ariake Sea is a semi-enclosed shallow embayment located in western Kyushu (Fig. 1). It has a large tidal amplitude up to 6 m of tidal range during spring tide in the bay head. Because of the shallow topography and large tidal amplitude, there are widespread of mud flat especially in the bay head. About 40% of the total tidal flat area in Japan are located in Ariake Sea. The Chikugo River which is the biggest river in Kyushu discharges into the bay head. High concentration of suspended clay and silt in the Chikugo River water, shallow depth and large tidal amplitude generate high turbidity and low transparency in the inner area of Ariake Sea. In Ariake Sea, Secchi disk depth increased from 1975 to 2005 (Nakata and Nonaka, 2003; Yokouchi et al., 2005; Kiyomoto et al., 2008). Nakata and Nonaka (2003) showed that such increase in transparency was not caused by the oceanic water supply from the bay mouth. Kiyomoto et al. (2008) suggested the relationship between the increase in red tide occurrence and enhanced transparency in the inner area of this bay in winter. They also suggested that one of the major factors leading to the increase of transparency was the decrease of resuspension of bottom sediments due to the reduced tidal current. On the other hand, Takeoka (2003) and Tai and Yano (2008) showed that the dominant variation in M2 tidal amplitude in Ariake Sea from 1969 to 2005 was 18.6 years lunar nodical cycle. This variation is larger than the long term trend. However, there is no variation in transparency with the period of 18.6 years. It suggests that other factors are important for the historical change in transparency.

The aim of this study was to determine the mechanism of the interannual variation in transparency in the inner area of Ariake Sea. For this purpose, the relationship between surface salinity and Secchi disk depth was analyzed. A 38 years monthly observation data of Secchi disk depth, temperature and salinity at 10 or 11 stations observed by the Saga Prefectural Ariake Fisheries Research and Development Center is available. During this period, several

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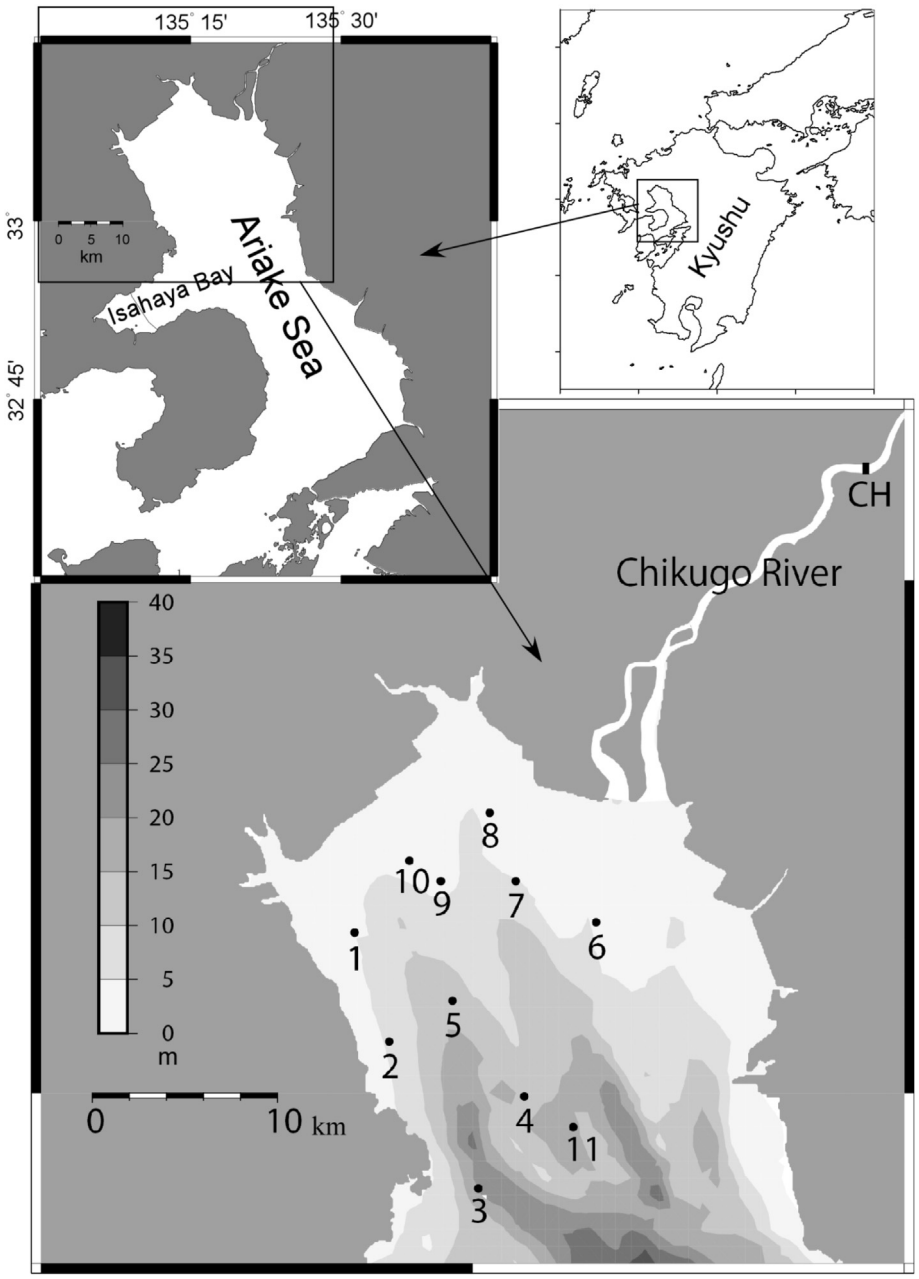

Fig. 1. Map of Ariake Sea and the location of the monitoring stations. CH indicates the Chikugo Ozeki weir.

coastal developments were conducted, including the Chikugo Ozeki weir and the Isahaya reclamation.

2. Data and methods

Secchi disk depth, temperature and salinity measurements were made monthly from April 1972 at 11 stations in the inner area of Ariake Sea (Fig. 1) by the Saga Prefectural Ariake Fisheries Research and Development Center. Only at the station 11, the monitoring started at June 1973. The observations were carried out basically during the high tide of the new moon during day time. We analyzed the data until March 2010 for 38 years. We also used the monitoring data taken by the Ministry of the Environment at 8 stations from February 2001 to January 2003 to estimate the relationship between transparency and suspended sediments (hereinafter, SS) at the sea surface. Hereafter the Secchi disk depth will be referred to *SD* and surface SS concentration will be written as *D*.

According to Yoshimura (1936) and Effler (1988), transparency (Secchi disk depth) is inversely proportional to the SS concentration or turbidity in the surface layer.

$$SD = N/D \tag{1}$$

Where N is a constant depending on the water body. Strictly speaking, there is the light absorption by water and dissolved matter,

$$D + \alpha = N/SD \tag{2}$$

where α is constant depending on the water body. Fig. 2 shows the relationship between *SD* and SS concentration (D) in the surface