Marine Pollution Bulletin 57 (2008) 103–107

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Analysis of change of red tide species in Yodo River estuary by the numerical ecosystem model

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ARTICLE INFO

Keywords:
Red tide
Estuary
Ecosystem model
Box model
Yodo River
Osaka Bay

ABSTRACT

Occurrence number of red tides in Osaka Bay in Japan is more than 20 cases every year. Diatom red tide was dominant in Osaka Bay, but the non-diatom red tide was dominant in early 1990s. Therefore, the material cycling in Yodo River estuary in Osaka Bay during August from 1991 to 2000 was analyzed by using the numerical ecosystem model and field observation data to clarify the reasons of change in red tide species. Year-to-year variation in calculated concentration ratio of diatom to non-diatom corresponds to the variation in observed ratio of red tide days of diatom to non-diatom. Limiting nutrient of primary production is phosphate over the period. Diatom dominated from 1991 to 1993, but it was difficult for non-diatom to grow due to the limitation by physical condition. Non-diatom was able to grow because of good physical and nutrient conditions from 1994 to 1996. And diatom dominated again under the good physical condition, and phosphorus supply was not enough for non-diatom to grow from 1998 to 2000. Phosphate concentration in the lower layer of Yodo River estuary was important to the variation in red tide species in the upper layer of Yodo River estuary.

1. Introduction

Red tides in Osaka Bay in Japan occur more than 20 cases every year. Osaka Bay is the semi-enclosed bay and located in the west of Japan as shown in Fig. 1. There are many factories and residential areas around Osaka Bay, moreover, the major rivers, Yodo River, Yamato River and so on, empty into Osaka Bay through the big cities, Kyoto, Osaka and so on. Much nutrient is loaded to Osaka Bay, and organic matter accumulates in the bottom and nutrients are released from the bottom sediment. Osaka Bay is one of the eutrophic areas in Japan, and the lower trophic level ecosystem of Osaka Bay is complex.

Diatom red tide was dominant in Osaka Bay but the occurrence number of non-diatom red tide was dominant in the early 1990s as shown in Fig. 2. Therefore, the reason of this remarkable change was investigated using the numerical ecosystem model including nitrogen, phosphorus and silicate cycling in August, summer in Japan, from 1991 to 2000.

2. Observed data

Analyzed area is the surface layer of Yodo River estuary in Osaka Bay shown in Fig. 1, where the red tide has occurred every summer, and analyzed period is August, summer in Japan, from 1991 to 2000. It is assumed as the one box with 3 m depth which is the mixed layer depth in summer in this area.

Fig. 3 shows the Yodo River discharge in August observed by the Ministry of Land Infrastructure and Transport (MLIT). Loading nitrogen and phosphorus from Yodo River were estimated by the river discharge, Total Nitrogen (TN) and Total Phosphorus (TP) concentrations in the downstream of Yodo River in August observed by MLIT. Dissolved Silicon (DSi) concentration in Yodo River was observed in August in 1973, 1995 and 2002 (Harashima et al., 2006; Mishima et al., 1999). The year-to-year variation of DSi concentration is small. Therefore DSi concentration in Yodo River is assumed constant of 108.8 μM during the analyzed period. Fig. 4 shows TN, TP and Total Silicon (TSi) fluxes from land area, which are the sum of the loading fluxes from Yodo River and the direct fluxes from plant around Osaka Bay.

Fig. 5 shows water temperature (a) and salinity (b) in Osaka Bay in August. And Fig. 6 shows Dissolved Inorganic Nitrogen (DIN) concentration (a), Dissolved Inorganic Phosphorus (DIP) concentration (b) and DSi concentration (c) in Osaka Bay in August. Fig. 7 shows chl.a concentration in Osaka Bay in August. These data were observed by Osaka Prefectual Fisheries Experimental Station and National Institute for Environmental Studies (Harashima et al., 1997). Photon in the water shown in Fig. 8 was estimated by light intensity observed by Japan Metrological Agency.

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doi:10.1016/j.marpolbul.2008.04.015

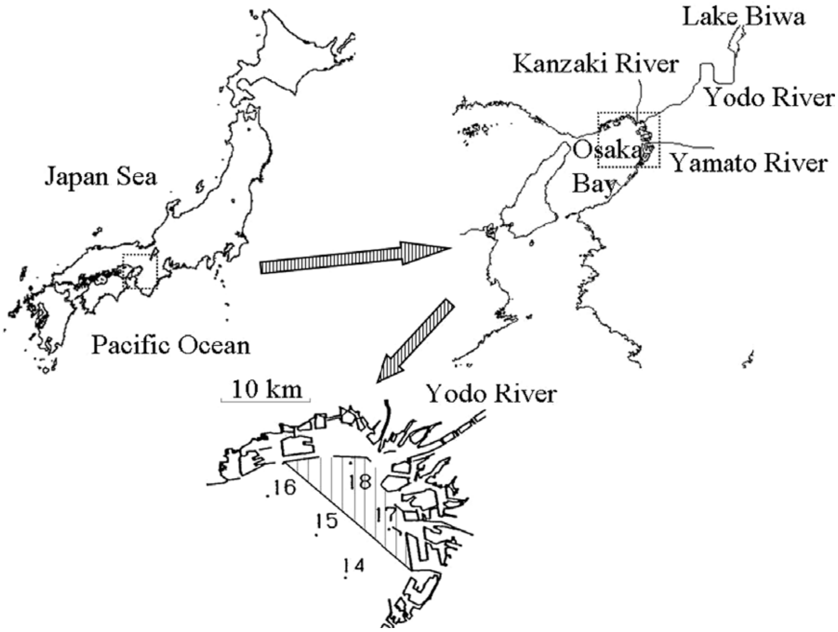

Fig. 1. Study area.

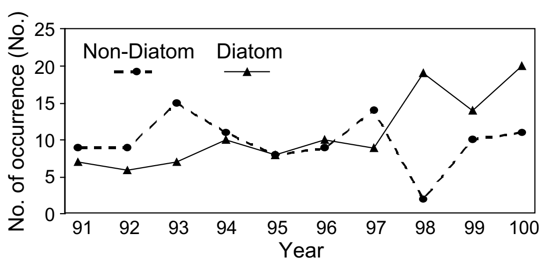

Fig. 2. Year-to-year variations in occurrence number of red tide in a year in Osaka Bay.

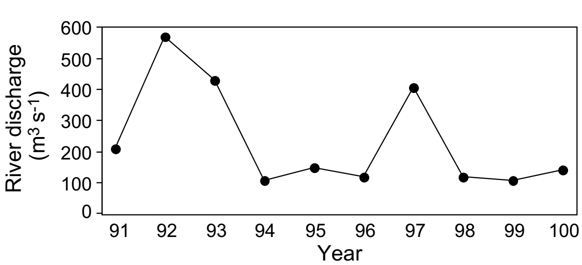

Fig. 3. Year-to-year variations in Yodo River discharge in August.

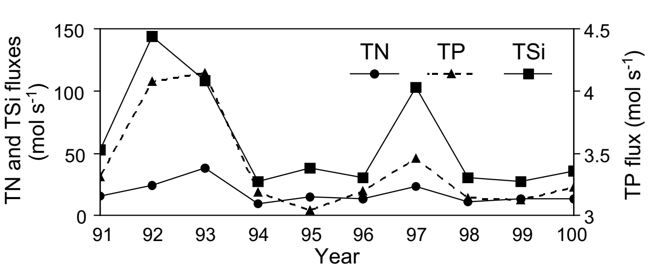

Fig. 4. TN, TP and TSi fluxes from land area in August.

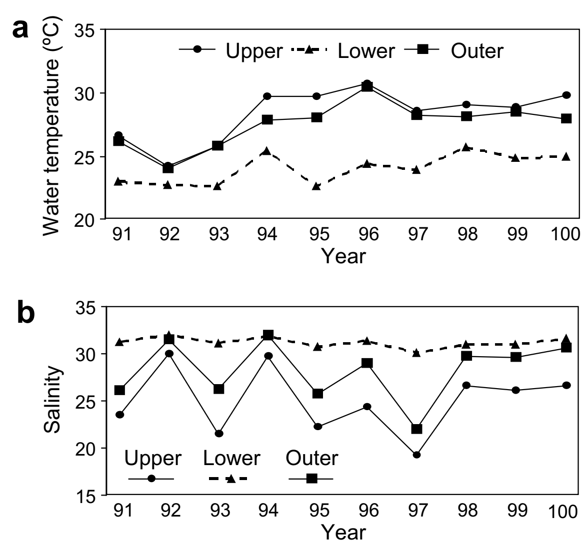

Fig. 5. Year-to-year variations in water temperature (a) and salinity (b) in Osaka Bay in August.

3. Numerical model

3.1. Ecosystem model

The numerical ecosystem model, shown in Fig. 9, has five compartments, nutrients (DIN, DIP and DSi), phytoplankton (diatom and non-diatom), zooplankton, detritus and Dissolved Organic Nitrogen and Phosphorus (DON and DOP). Material cycling in the box is based on the biochemical processes between compartments. And also, the model includes material load from the land area, sinking of diatom and detritus, diurnal motion of non-diatom and advection and diffusion related to the estuarine circulation. Temporal change in concentration of each compartment is represented by the equations. For example, Eq. (1) represents the temporal change in DIP concentration. It consists of three parts, biochemical process, boundary condition and physical process.