Estuarine, Coastal and Shelf Science 116 (2013) 21–28

Contents lists available at SciVerse ScienceDirect

Estuarine, Coastal and Shelf Science

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

Effects of desiccation and salinity on the outbreak of a green tide of *Ulva pertusa* in a created salt marsh along the coast of Osaka Bay, Japan

Susumu Yamochi

Laboratory of Estuarine and Coastal Ecosystem Engineering, Department of Urban Engineering, Graduate School of Urban Engineering, Osaka City University, 3-3-138, Sugimoto, Sumiyoshi, Osaka 558-8585, Japan

ARTICLE INFO

Article history:
Received 23 September 2011
Accepted 1 July 2012
Available online 7 July 2012

Keywords:
green tide
Ulva
benthic microalgae
artificial salt marsh
desiccation
low salinity
Osaka Bay

ABSTRACT

Field surveys and laboratory experiments were conducted to examine the effect of desiccation and salinity on the outbreak of a green tide of *Ulva pertusa* at Osaka Nanko bird sanctuary. Reduction of biomass of *Ulva* spp. was observed at stations where the exposure rate to air was from 30 to 40%. In addition, the exposure rate of 30–40% to air showed no negative impacts on the biomass of benthic microalgae, infauna and non-motile epibenthos. Laboratory experiments revealed that photosynthetic activity of *U. pertusa* decreased when exposed to air for 4–7 h at 25–35 °C. Salinity decreases from 30 to 25 or 20 accompanied with exposure to air drastically reduced the rate of photosynthesis of this species. These results suggest the possibility of controlling a green tide of *U. pertusa* without serious physico-ecological damage to benthic microalgae, infauna and non-motile epibenthos by a combination of exposure to air with low salinity.

1. Introduction

Many natural intertidal flats and salt marshes disappeared from temperate sea coasts of Japan in the 1980s due to land reclamation for urban development and factory construction. However, intertidal flats and salt marshes are now thought to have important functions for water purification, biological diversity and nursery grounds for juvenile organisms as well as amenity spaces for citizens (Costanza et al., 1997). These ecological values of the natural intertidal flat and/or salt marsh have led to the construction of artificial intertidal flats or salt marshes along the coasts of urban areas in Japan (Yamochi, 2007). In addition, the Law for the Promotion of Nature Restoration of Japan was established in 2003 by the Ministry of the Environment to restore deteriorated ecosystems and natural environments. This law also defined the legal position for the conservation and restoration of ecosystems. However, there are so far some problems in Japan in terms of the construction of artificial intertidal flats or salt marshes as follows:

1) It is difficult to secure a sufficient area to construct an artificial intertidal flat or salt marsh;
2) Artificial intertidal flats or salt marshes need to be repaired and managed properly after construction;
3) Dense blooms of green algae (green tides) frequently occur at temperate and eutrophicated intertidal flats or salt marshes (Yabe et al., 2009).

Some species of the genera *Ulva*, *Enteromorpha*, *Chaetomorpha* and *Cladophora* are major seaweeds which form green tides at the eutrophicated shallow waters, intertidal flats and salt marshes of the world (Fletcher, 1996). Green tides are now widely recognized as a common and detrimental phenomenon since thalli of the seaweed entirely cover the surface of the bottom sediment and cause deterioration of quality of the bottom sediment. Dense green tides also lead to a sharp decrease in the number of infauna and non-motile epibenthos. Further, a large quantity of deteriorating seaweeds accumulate on the upper area of the intertidal zone of the flat and spoil the scenic value and cause unpleasant odors. At present there is nothing we can do but remove by hand the mass of green tides to reduce the damage against intertidal flat or salt marsh ecosystems.

In the present study I examined the population dynamics of *Ulva* spp. at the north salt marsh of Osaka Nanko bird sanctuary in the high temperature seasons of 2006–2008 when dense green tides were frequently observed. Besides, I selected salinity and

E-mail address: yamochi@urban.eng.osaka-cu.ac.jp.

0272-7714/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.ecss.2012.07.002

desiccation as target environmental parameters which we can manage to control at the lagoon-type artificial salt marsh. It is possible to change salinity and exposure rate to air (=ground level) by reserving rainwater and by engineering works. In contrast, it is difficult to control temperature or light intensity at the man-made salt marsh as a matter of practicality. Therefore, laboratory experiments were carried out on the response of *Ulva pertusa* to salinity and desiccation. Based on the results obtained, I discuss the possibility of reduction of green tides at the eutrophicated intertidal zone of the lagoon-type artificial salt marshes in the vicinity of urban areas.

Although the most dominant species of *Ulva* is *Ulva pertusa* at Osaka Nanko bird sanctuary, I refer here to seaweed samples of the bird sanctuary as *Ulva* spp. since the samples may have contained *U. pertusa*, *Ulva ohnoi* and small amounts of *Ulva fasciata*. In contrast, *U. pertusa* was used as the scientific name for the laboratory experiment because the morphological features were examined according to Hiraoka et al. (2003).

2. Methods

2.1. Field surveys 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 Nanko District, Osaka Port, central Japan (Fig. 1). This lagoon-type artificial bird sanctuary is composed of a north salt marsh (4.0 ha), south salt marsh (3.8 ha), west pond (1.4 ha) and reed fields. The north and south marshes were built by capping with sand over the dredged sediment. Six sluice pipes (74 cm in diameter) were installed through the seawall in 1995 for the north salt marsh and four sluice pipes (80 cm in diameter) in 2004 for the south salt marsh. The ground level of the bottom tip of the sluice pipe is L.W.L (Low Water Level) +0.20 m for the north salt marsh and L.W.L.+0.65 m for the south salt marsh, which enables seawater to flow in or out to Osaka Bay by 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 low water of spring tides. The south salt marsh shows almost the same ground level (L.W.L.+0.73 m) with the north salt marsh but less emergent depending on the difference of the ground level of the bottom end of the sluice pipes between the two salt marshes. The averaged exposure rate to air in areas of the north and south salt marshes is 17.3% and 9.2%, respectively (Table 1).

Dense green tides have been observed since 1995 at the north salt marsh and since 2005 at the south salt marsh, which approximately coincided with year when sluice pipes were constructed and salinity increased. Dominant seaweeds are different between the two nutrient-rich salt marshes; namely, *Ulva pertusa* and *Ulva ohnoi* are abundant at the north salt marsh, while a Chlorophycean seaweed *Rhizoclonium* sp. predominates at the south salt marsh.

2.1.2. Sampling and analysis

Seaweed samples of *Ulva* spp. were taken 7 times in high water temperature seasons of 2006, 2007 and 2008 at 26 stations of the north and south salt marshes with a 0.25 m^2 quadrat and wet weight of each seaweed sample was measured. Bottom sediments were taken with a small acrylic pipe (ca. 2 cm in diameter) and with a modified Koken grab (0.045 m^2 in sampling area) at 9 stations of the north salt marsh. A sample of the surface layer of the bottom sediment (0–0.5 cm depth from the surface) of the acrylic pipe was employed for the measurement of biomass of benthic microalgae. For determination of the biomass of benthic microalgae, the concentration of chlorophyll a of the bottom sediment was analyzed by the fluorometric method using a Turner Designs Fluorometer (Model 10-AU-005). Silt and clay content of the bottom sediment was determined following the method by Arakawa (1980). Measurements of carbon and nitrogen in the bottom sediment were carried out with a Yanagimoto CHN analyzer (Model MTS-5). The bottom sediment in the grab was sieved through a 1 mm mesh net and preserved in ca. 10% formalin, then

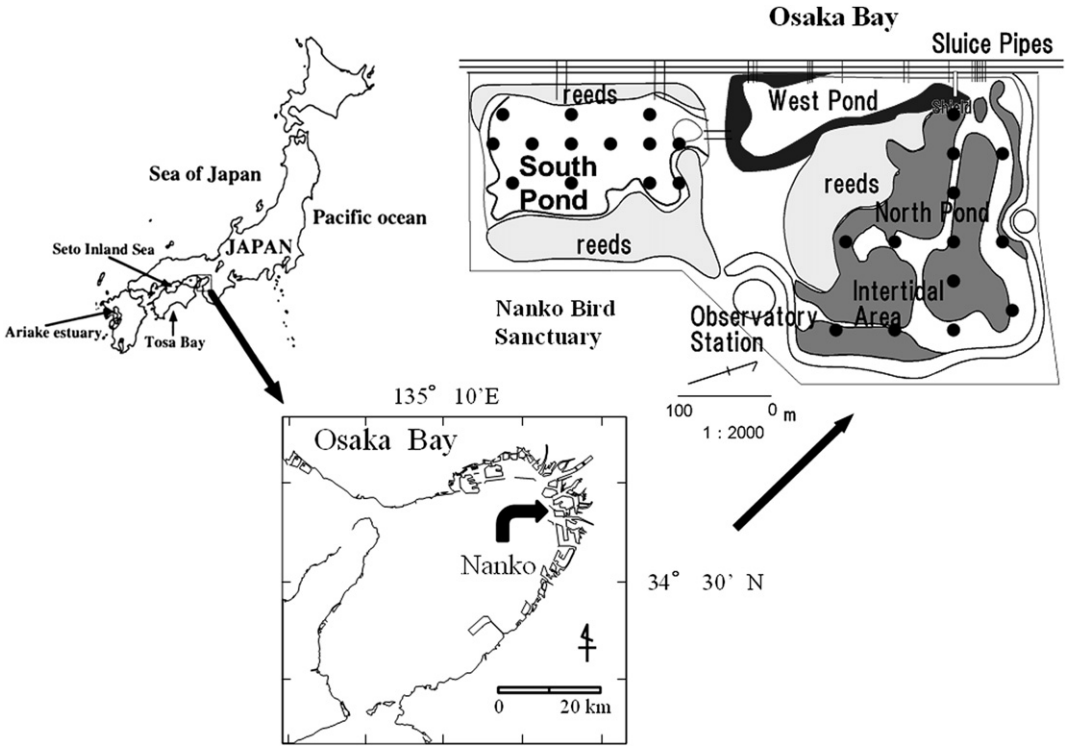

Fig. 1. Map showing the sampling stations (●) at the north and south salt marshes of Osaka Nanko bird sanctuary along the northern coast of Osaka Bay, Japan.