Marine Pollution Bulletin 75 (2013) 98–104

Contents lists available at ScienceDirect

Marine Pollution Bulletin

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

Physico-chemical and nutrient variable stratifications in the water column and in macroalgal thalli as a result of high biomass mats in a non-tidal shallow-water lagoon

Mauro Lenzi [a,*], Paola Gennaro [b], Isabel Mercatali [b], Emma Persia [b], Duccio Solari [a], Salvatore Porrello [b]

[a] Lagoon Ecology and Aquaculture Laboratory (LEALab), Orbetello Pesca Lagunare Company, Via G. Leopardi 9, 58015 Orbetello, Italy
[b] Higher Institute for Environmental Protection and Research (ISPRA), Via di Casalotti 300, 00166 Rome, Italy

ARTICLE INFO

Keywords:
Eutrophication
Macroalgal mat
Macroalgal thalli
Nutrient
Shallow water
Top–bottom stratification

ABSTRACT

A field study to check parameter stratification during high density growth of four opportunistic macroalgae was carried out in Orbetello lagoon (Italy). The effects of macroalgal masses were compared with a seagrass meadow and two lagoon areas with bare bottoms as controls for pH, temperature, dissolved oxygen, salinity, nitrite, nitrate ammonium and orthophosphate. The nutrient content of thalli and sediment redox were measured. Macroalgae showed differences in stratification of thalli nutrient content. Mat with low density and high volume produced stratifications in the water column, but it did not produce nutrient release by sediment. In contrast, high density and low and high volume mats led to sharp falls in dissolved oxygen, with negative values of sediment Eh and anoxic trigger processes that presumably led to release of sediment nutrients. This depended on thallus type: heavy thalli compacted the mat and light ones distributed more widely in the water column.

1. Introduction

In shallow eutrophic coastal ponds and lagoons, macroalgal blooms are a frequent source of problems. Opportunistic macroalgae tolerate the indirect effects of eutrophication, such as anoxia and elevated concentrations of N compounds, that they themselves cause at high density (Gordon et al., 1981; Peckol and Rivers, 1995a,b), showing rapid growth and high uptake of N and P (Littler and Littler, 1980; Rosemberg and Ramus, 1984). They therefore remove, store and release large quantities of dissolved nutrients (Ryther et al., 1981), playing a major role in the macronutrient cycles of these environments. The nutrients may later be used, avoiding growth limitation when dissolved nutrients become scarce (Lavery and McComb, 1991a). When macroalgae finally decompose they become a nutrient source (Sfriso et al., 1987; Hanisak, 1993). Thus simple monitoring of nutrients in the water column may not provide enough information to describe the trophic status of a basin.

Opportunistic macroalgae that develop in shallow eutrophic lagoons occur as pleustophytic thalli, often forming high density masses of a single species (Menesguen and Piriou, 1995; Bombelli and Lenzi, 1996). As they are herded by wind, these masses accumulate in preferential low energy areas, and start to degenerate from the bottom under suitable conditions of density and temperature. The opportunistic macroalgae *Gracilariopsis tikvahiae* and *Cladophora vagabunda* have been shown to have physiological responses allowing them to survive high density stress (Peckol and Rivers, 1995a).

Due to the shallow depth and low water turnover of most Mediterranean lagoons, the water column may be completely occupied by macroalgae. Such thick mats prevent light from reaching underlayer vegetation, causing physical–chemical stratification in the water column, including stratification of nutrients (Krause-Jensen et al., 1996; McGlathery et al., 1997). Dense macroalgal mats "develop anoxic or low oxygen concentrations in inter-algal water and derive nutrients from sediment to support further growth" (Lavery and McComb, 1991a). According to Lavery and McComb (1991b), "dense accumulations of *C. linum* have a demonstrated ability to induce sediment phosphorus flux through their effect of reducing oxygen levels in the overlying water, resulting in high P concentrations in the inter-algal water". Under bright light conditions, where productivity is highest in the upper layer of the mat and N availability from upward diffusion of benthic flux is low due to under-layer macroalgal uptake, N must be obtained from the water column, causing a downward flux of nutrients from surface water into the mat top layer (McGlathery et al., 1997). Under these conditions, phytoplankton growth is limited and the water is clear, despite effectively high eutrophication (Sfriso et al., 1992). On the contrary, under dim light conditions, macroalgal uptake from the benthic nutrient flux is much reduced and may rise in the water

* Corresponding author. Tel.: +39 0564860288; fax: +39 0564867572.
E-mail address: lealab2@hotmail.com (M. Lenzi).

0025-326X/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.marpolbul.2013.07.057

column to the over-layer (McGlathery et al., 1997). Depending on their stages and meteorological conditions, thick dense macroalgal mats may give rise to a variety of environmental conditions.

The aim of this field study was to highlight physico-chemical and nutrient stratification in the water column and mats, and its effects on under-mat sediment, in the case of masses of four widespread opportunistic macroalgae having different thallus morphologies, which were compared to those produced by seagrass meadows and bare bottoms.

2. Materials and methods

2.1. Study area

Orbetello lagoon is a shallow eutrophic environment with low water turnover in southern Tuscany (Italian west coast; 42°25′–42°29′N, 11°10′–11°17′E). It consists of communicating western (15.25 km^2) and eastern (10.00 km^2) basins (Fig. 1). Eutrophication is due to wastewater of land-based fish farms and the input of an intermittent stream receiving agricultural run-off and civil effluent. Until a few years ago, treated urban wastewater was also discharged into the lagoon close to the town of Orbetello (Lenzi et al., 2003). Because of high nutrient availability, severe macroalgal proliferations developed in the lagoon, causing frequent dystrophic crises, subsequently partly remedied by macroalgal harvesting (Lenzi, 1992; Lenzi et al., 2011).

2.2. Experimental design

A field study was conducted in July 2008 to determine the physico-chemical and nutrient conditions occurring in high density opportunistic macroalgal mats compared to two bare bottom areas and a seagrass meadow. The species monitored were ruling species that produced the highest accumulations of biomass (Lenzi et al., 2009): the red alga *Gracilariopsis longissima* (Gmelin) Steentoft, Irvine et Farnham, and the green algae *Ulva laetevirens* Areschoug, *Cladophora vagabunda* (L.) C. van D. Hoek and *Chaetomorpha linum* (Müller) Kützing. The seagrass used for comparison was *Ruppia cirrhosa* (Petagna) Grande, which produces extensive meadows in central areas of the lagoon. In the mats observed, only one species was dominant (over 90% in weight). The sampling stations were selected after a preliminary survey to check that algal thalli in the mats were not decomposing, that the meadow was homogeneous, that algae in the meadow were negligible and that the bare areas lacked vegetation over an surface of at least 100 m^2. The sampling stations were chosen where growth conditions of the species were likely to be almost monoxenic (Fig. 1): station G, a mat of *G. longissima* near where urban wastewater was discharged in the recent past; station U, a high density mat of *U. laetevirens* near where land-based fish farm wastewater is discharged; station C, a mat of *C. vagabunda* near where wastewater from the urban water treatment plant was discharged until a few years ago; station CH, a mat of *C. linum* in a eutrophic marginal area with low water turnover; station R in the middle of a large *R. cirrhosa* meadow far from urban areas. The control stations were BW and BE, located in areas bare of vegetation in the western and eastern basins.

The search for largely monoxenic mats with high biomass led to selection of very different sampling stations, difficult to compare. This also applied to sediment texture, which certainly varied between stations, with different percentages of calcareous detritus, fine sand and clay. These percentages were computed as the average of two records obtained from the data-set of Renzi et al. (2007) for sites close to the stations of this study. The different environmental conditions of the stations were determinants of monoxenic growth and high-biomass, and were therefore unavoidable in order to study stratifications in the mats and respective water columns, and the effect of different mat densities on sediment, which were aims of the study.

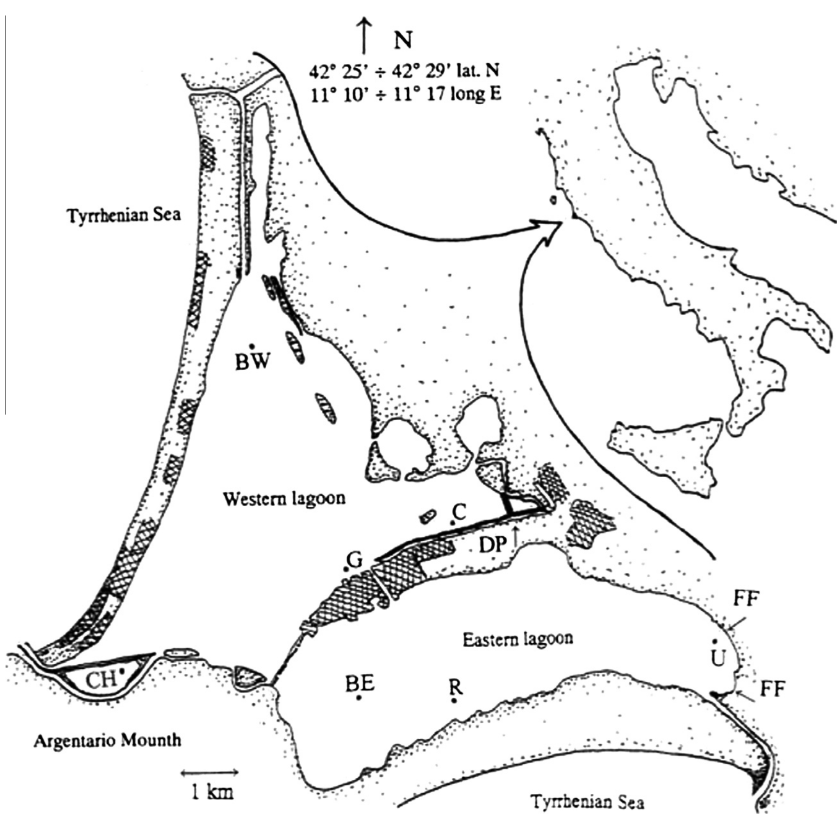

Fig. 1. Orbetello lagoon with sampling points (C, G, U, CH, R, BW, BE), urban treatment plant (DP), land based fish-farm (FF).