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Modeling *Ulva* spp. dynamics in a tropical upwelling region

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Abstract

The development and application of a model to represent the seasonal dynamics of *Ulva* spp. biomass at the Cabo Frio tropical upwelling region is here described. In addition to biomass, the model simulates nitrogen and phosphorus internal concentrations in the algae. The factors considered to affect algal growth at Cabo Frio are sunlight, water temperature, nitrate, ammonium and phosphate, and the alga carrying capacity. Peaks in algal abundance (up to 1000 g d.wt./m^2) were observed to occur and were simulated by the model during the upwelling season. The inclusion of a variable optimum temperature was found to be necessary to avoid a phase lag between model and observations. Calibration of some of the model parameters with a simplex method has further improved the model results. The simulations shown here suggest that the initial growth of *Ulva*, after a downwelling period, is stimulated by the increase in nutrient concentrations in the water column during upwelling.

Keywords: *Ulva* dynamics; Upwelling; Calibration; Seasonality; Brazil

1. Introduction

The Cabo Frio region, located in the southeastern coast of Brazil (23°01′S, 42°00′W), is affected by a seasonal upwelling of cold subsurface waters. This phenomenon has been shown to cause an increase in algae productivity during the spring–summer months (Coutinho et al., 1989) particularly at sites influenced directly by the cold nutrient rich waters. Therefore, our main hypothesis is that the control of algal seasonality is related to the increase of nutrients in the water column, especially nitrate (Guimaraens and Coutinho, 2000). The statistical analyses conducted by Guimaraens and Coutinho (2000) suggest that the spatial and temporal variation of temperature and nutrients (nitrate, ammonium and phosphate) is correlated to algal percent cover variation. However, field data show that in some occasion algal growth do

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not respond to nutrients increase in the water column (Guimaraens and Coutinho, 2000). Therefore, in the present paper we used model simulations to explore the effect of other environmental factors on algal seasonality such as temperature.

Ulva is an ephemeral alga with limited storage capacity (Fujita, 1985) and little defense against herbivores (Lobban and Harrison, 1994). At the Cabo Frio region it has higher production rates in areas affected by upwelling than in non-upwelling areas (Coutinho et al., 1989). The simulation effort focuses on *Ulva* because it is one of the dominant species at upwelling sites (Guimaraens, 1999) and because there is also plenty of literature available on physiological parameters for this alga.

This work describes the development and implementation of a differential equation non-linear model, which simulates algae biomass. The model is used in order to investigate the factors that affect the growth and the seasonal dynamics of *Ulva* spp. at the Cabo Frio upwelling region. In addition to nutrient concentration and uptake by the algae, solar radiation, and water temperature and algae carrying capacity are taken into account. The last two are shown to be determinant factors, together with variations in the nutrient availability in the water during the upwelling cycles, in the study region.

The paper is organized as follows. In Section 2, the physical and biological systems of the Cabo Frio upwelling are described, and the environmental data used in the model simulations are presented. The model equations and configuration are described in Section 3, and preliminary experiments, conducted to evaluate the model limitations and possible solutions, are presented in Section 4. In Section 5, the model is calibrated and results are presented for two sites under different upwelling conditions and for different levels in the rocky shore. The results are then summarized and discussed in Section 6.

2. Description of the Cabo Frio upwelling system

2.1. Physical system

The non-upwelling period at the Cabo Frio region is characterized by warm waters, with temperatures generally above 21 °C, and nutrient concentration, nitrate and phosphate, below 1 and 0.4 μg-at. l^{-1}, respectively. Temperatures below 18 °C, sometimes as low as 13 °C, and high nitrate and phosphate concentration, around 10 and 0.8 μg-at. l^{-1}, respectively, (Guimaraens and Coutinho, 1996; Guimaraens and Coutinho, 2000) characterize the upwelling conditions (Figs. 1 and 2). The upwelling phenomenon leads to a phase shift of the normal seasonal cycle for this latitude, with lower water temperatures observed during spring and summer, and higher water temperatures occurring during fall and winter.

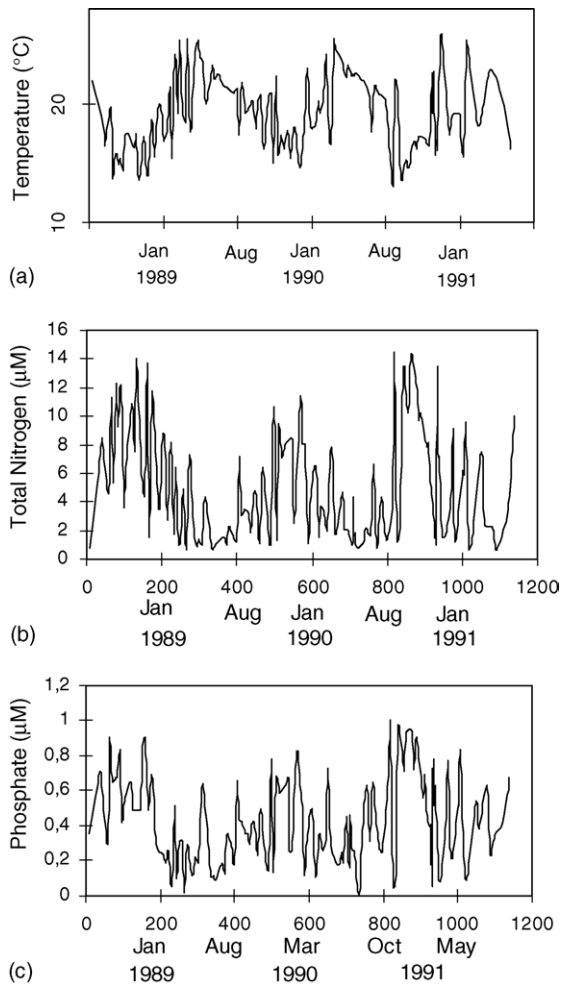

Fig. 1. Observed SST (a), total nitrogen (b) and phosphate (c), from 1988 to 1991 at an upwelling site (Sonar) in Cabo Frio.