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Production and biomass accumulation of periphytic diatoms growing on glass slides during a 1-year cycle in a subtropical estuarine environment (Bay of Paranaguá, southern Brazil)

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Abstract Production rates, chlorophyll concentrations and general composition of periphytic diatom communities growing on glass slides were studied in relation to environmental parameters during one seasonal cycle in the Bay of Paranaguá, southern Brazil. Slides were routinely submersed at 1, 2 and 3 m depth and recovered weekly for microscopic examinations, analyses of chlorophyll, cell counts and in situ photosynthetic incubations using the Winkler titration method. Water samples were also collected at surface and bottom layers for determinations of temperature, salinity, nutrients and chlorophyll in the water. The periphytic community was mainly formed by epipelagic and epipsammic species, dominated by Navicula phyllepta, Cylindrotheca closterium, Navicula spp. and Amphora sp. Weekly chlorophyll a and cell accumulations on slides varied from <1–32 mg m⁻² and up to 31 x 10⁶ cells m⁻², respectively. Photosynthetic rates varied from <1 to 35 mg oxygen mg chlorophyll a⁻¹ h⁻¹, with higher values in summer. Daily production varied from 5 to 3,600 mg oxygen m⁻² day⁻¹ (<0.01–1.4 g carbon m⁻² day⁻¹). Multiple regression analysis revealed that vertical differences in light conditions and grazing pressure jointly affected the influence of temperature on the seasonal patterns of cell densities and chlorophyll concentrations according to depth.

Introduction

Benthic diatoms are important microautotrophs in marine habitats, growing on a great variety of substrates (Grontved 1960; Amskoven and McIntire 1978; Rioux-Gobin 1987; Sullivan and Moncrieff 1988; MacIntyre and Cullen 1995). Most common are pennate epipelic diatoms that develop on intertidal mudflats along temperate and subtropical estuarine environments (Admiraal et al. 1982; Amskoven and McIntire 1986; Laird and Edgar 1992).

In addition to their importance as food for benthic invertebrates (Pace et al. 1979; Decho and Fleeger 1988; Sullivan and Moncrieff 1990) they supply organic carbon to the planktonic system during resuspension by tidal currents and wind-induced turbulence (Brown and Austin 1973; Demers et al. 1987; Wainright 1990; Delgado et al. 1991; de Jonge and van Beusekom 1992).

Epipelic diatoms are usually the dominant microautotroph on mud flats in the inner intertidal zones of the Bay of Paranaguá, a mangrove-bordered subtropical lagoon environment in southeast Brazil. A significant role in the food-web of the bay is confirmed by the dominance of diatoms in the digestive tracts of most benthic invertebrates (P. Lana, personal communication). Resuspended diatoms also contribute to the biomass of the water column over the entire bay (Brandini and Thamm 1994; Brandini and Fernandes 1996). Except for taxonomic studies (Moreira-Filho and Kutner 1962; Moreira-Filho et al. 1975), basic ecological and quantitative information on the benthic diatoms in the Bay of Paranaguá remains unknown. This investigation describes the seasonal pattern of periphytic diatom populations growing on glass slides in the Bay of Paranaguá in relation to environmental parameters. Our goal was to gain new insight into the ecological role of benthic (mostly epipelic) diatoms in a shallow subtropical mudflat habitat.
Materials and methods

Field work

The pier of Pescaí Fisheries, located at the southwestern margin of Galheta Channel at the entrance of the Bay of Paranaguá, was selected as the study site. This site is hydrographically representative of the western sector of the bay, where mudflats are extensive (Fig. 1a). Sets of 12 acid-cleaned glass slides (1 x 5 cm) were arranged on three plexiglass plates (four slides on each plate). The plates were attached to an anchored line at 1, 2 and 3 m depth, respectively (Fig. 1b). Slides were kept horizontal with both sides exposed for colonization. The mean area of the 46 slides available for colonization was 10.2 cm². The suspension line was tied to a buoy and anchored to the bottom. To keep the line vertical and to level the plates with tidal changes in water height, the buoy was also tied to the pier columns by a combination of ropes and rubber extensors. This was done to keep the slides at the same respective depth and to avoid exposure of the 1-m-deep plate during low tide.

After 7 days of submergence, the slides were collected and replaced by a new set of acid-cleaned slides. Sampling was conducted this way from 1 November 1993 to 24 October 1994, always between 0900 and 1000 hours. Slides were placed into glass production flasks and into test tubes for photosynthetic experiments (n = 5) and chlorophyll determinations (n = 5), respectively. In the field, two slides from each depth were used for in situ measurements of photosynthetic rates by the oxygen light-and-dark incubation method. After incubation, the slides were gently immersed in ambient water and transported to the laboratory inside a cool, dark container for analyses of species composition and chlorophyll accumulation.

Environmental parameters

Both at low and high tide on the sampling days, Secchi depths were determined and samples of surface and bottom waters were collected for subsequent measurements of temperature (mercury thermometer), salinity (refractometer), and concentrations of nitrate, phosphate and silicate by colorimetric techniques (Strickland and Parsons 1972). Chlorophyll a in surface waters was also determined by spectrophotometric readings of 90% acetone extracts (Jeffrey and Humphrey 1975) following the filtration techniques of Strickland and Parsons (1972). Daily incident photosynthetically active radiation (PAR) was monitored continuously by a Biospherical Instruments QSR-240 radiometer, and daily precipitation was supplied by the meteorological stations at Morretes, Antonina and Paranaguá cities.

Analyses of cell accumulation and species composition

For enumeration, the periphytic material was carefully scraped off one slide from each depth, diluted with pre-filtered (Whatmann GF/C filters) seawater to final volumes of 17-58 ml, and fixed with 1% formalin solution. Two procedures were adopted for analysing these samples. A 0.1-ml aliquot was placed on a microscope slide, on which the most abundant and smaller cells (< 100 µm) were counted in transects of 4.5 mm², under 320 x total magnification using a Zeiss inverted microscope equipped with phase contrast. Second, a 2-ml aliquot was sedimented according to the Utermühl (1958) technique and the whole chamber bottom was examined at 80x magnification with a Zeiss inverted microscope, for enumeration of cells larger than 100 µm. Total cell densities in terms of cells per square centimetre were estimated, accounting for the substrate area (i.e. 10.2 cm²), counting area under the microscope, and volume of filtered seawater used to dilute the periphytic material.

Two procedures were adopted for analysing the general composition of diatoms that settled during the 7 days of submergence: (1) in vivo microscopic analysis of periphytic composition over one entire slide of the 1-m set; (2) for more precise taxonomic determinations, the material stripped from the slides after the in vivo analysis was cleaned with potassium permanganate, with the addition of oxalic acid, and washed with distilled water until the appropriate pH was reached. Permanent slides were prepared according to Reid (1978), using Naphrax as the mounting medium. Light microscopy was performed with an Olympus BX40 microscope using an 100 × oil immersion objective.

Chlorophyll a accumulation per unit area

Slides from 1, 2 and 3 m depth and those originating from the photosynthesis experiments were transferred to test tubes and kept immersed in 6 ml of 90% acetone for 24 h under dark refrigeration (4 °C). The slides were then washed with acetone and final acetone extracts were diluted to a final volume of 8 ml. After sample centrifugation, spectrophotometric techniques were used for measuring chlorophyll concentrations in the extracts following the

Fig. 1 Map of the Bay of Paranaguá showing the sampling site (a) and details of glass slides support attached to the pier (b)