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Original Research Article

Seasonal variation of phytoplankton indicates small impacts of anthropic activities in a Brazilian Amazonian reserve

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ABSTRACT

Knowledge about phytoplankton community structure helps in assessing the quality of a water body. However, variables related to it are not routinely surveyed in most of the water quality monitoring programs. Our approach included studying the diversity of these organisms, in a large tropical reservoir in a Brazilian Amazonian reserve. The research was carried out in the rainy and dry season when measurements were performed every three hours and at five different depths. A total of 40 water samples were collected to analyze temporal variations of abiotic and biotic factors. Physico-chemical parameters were analyzed to characterize the ecosystem and relationships between these variables and phytoplankton functional groups were statistically tested. The data were examined using analysis of variance and canonical correspondence analysis. We identified 9 functional groups in both seasons. The functional group M, which represents organisms with developed adaptations to high insolation and stable environments, had a higher relative percentage of contribution to the total biomass in the rainy season. Group P, which tends to be present in the more eutrophic lakes and is tolerant to carbon deficiency, had a higher relative percentage of contribution to the total biomass in the dry season. This study indicated that the fluctuations of the water level reflected in seasonal changes of phytoplankton biomass and environmental variables. Additionally, this experiment permitted to advise on sampling strategies for monitoring phytoplankton in lakes and reservoirs.

1. Introduction

The main rivers of the Brazilian amazon rainforest are being exploited for purposes of hydroelectric generation. Extensive constructions of reservoirs produced huge impacts to the aquatic ecosystems of the watershed in the last years (Tundisi et al., 2006).

Uncontrolled land occupation and use by populations living along reservoir areas are a negative impact, which favors the increase of pollution sources to the water body. Sources of pollution in aquatic ecosystems are mainly from the discharge of sewage, pesticides from agricultural and reforestation uses. These factors contribute to the increase of nutrients (N and P) in the water body, consequently favoring eutrophication (Straskraba and Tundisi, 2013).

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Studies on the functional roles and structural adaptations of planktonic organisms are a subject of very interest by researchers' worldwide (Reynolds et al., 2002). The study of planktonic organisms is of great ecological importance because phytoplankton produce organic matter by photosynthesis and so represent the base of the food chain (Lee, 2008). Moreover, they are considered as a good indicator of the physical and chemical conditions of water in reservoirs due to their diversity index assessment (Costa et al., 2009). The diversity of planktonic organisms and their various compositions may signal the deterioration of a water body as they grow excessively under water-rich nutrient conditions (Bilous et al., 2016; Tundisi and Tundisi, 2012).

Phytoplankton are autotrophic organisms that are present in most freshwater basins. These organisms have the tendency to perform vertical migration as a result of any significant change that occurs in the water environment (Mellard et al., 2011). This ability to regulate in a vertical position is related to their intrinsic features (such as flagella, walls, and mucilages, plastids, *etc.*) and extrinsic features related to the water movements and changes in variables such as temperature, nutrient loading and light availability as described by Xu et al. (2011); Carl et al. (2004). Furthermore, when in functional group association, phytoplankton provide a better understanding of the ecosystem dynamics and species selection (Okogwu and Ugwumba, 2012).

Artificial ecosystems such as hydroelectric reservoirs are lakes which are continually manipulated by human activities. They are intermediate ecosystems between lotic and lentic environments (Margalef, 1983). In addition, reservoirs are important not only for electrical power generation but also for their multiple roles such as water supply, flood control, and navigation. However, human activities such as fisheries and recreation in these artificial lakes have been reported as the main cause for eutrophication occurrence (Straskraba and Tundisi, 2013).

Eutrophication of water bodies is characterized by excessive production of phytoplankton biomass, which is usually associated with increasing of nutrients concentration, such as phosphorus and nitrogen (Ansari et al., 2011). High phytoplankton biomass is known as "*algae blooms*" and these can be harmful to human health having a drastic effect on the quality and availability of water for various purposes (Tundisi et al., 2004). Harmful algae "*blooms*" cause esthetic degradation of lakes and reservoirs resulting in the formation of foam on the water surface, unpleasant taste and odor in drinking water and health effects from the toxins present in some of these algae (Smith and Schindler, 2009a; Smith and Schindler, 2008; Smith and Schindler, 2009b).

In this work, the main goal was to investigate phytoplankton response to the effect of the nutrient load at the surrounding areas of a Brazilian Amazonian reserve. Thus, as phytoplankton perform vertical migration as a result of any change in the environment, we proposed to take measurements in temporal and vertical scales. According to Mellard et al. (2011), the vertical dimension is the major axis responsible for explaining phytoplankton heterogeneity due to its effect on primary production as well as energy transfer to high trophic levels (Lampert et al., 2003).

In addition, we hypothesized that there is a correlation between the diurnal and seasonal variations in vertical distribution of phytoplankton with nutrient loads likely caused by human activities, such as fish-farming and recreation.

2. Materials and methods

2.1. Description of study site

The study area was the Alcobaça Sustainable Development Reserve (SDR) which is located in the Tucuruí reservoir, the second largest in Brazilian territory (Espíndola et al., 2000). This SDR extends from 3°50′32.8″ S to 49°40′38.8″ W to 4°3′49.6″ S to 49°55′ 36.1″ W and occupies 36.128,00 ha of the protected areas around the Tucuruí reservoir (Fig. 1).

The Alcobaça SDR is part of a mosaic of protected areas dedicated to biodiversity conservation. The main characteristic of this reserve is the presence of several islands, which were formed by the Tucuruí dam. According to Barata (2011), the environmental characteristics of this RDS remain with little changes and huge biodiversity. In spite of the legislation prohibits any predatory exploitation of the natural resources, the RDS has being occupied without planning. This issue direct affects forestry resources, which has to be cut-off for land occupation.

This Amazonian SDR has faced problems related to deforestation along last decade but it is decreasing as showed in Fig. 2b (INPE, 2017). This process has serious consequences such as soil erosion, leaching, disturbance of the water, oxygen, and carbon dioxide cycles. The leaching of soil, during rainfall periods and high waters, loads organic matter into the aquatic environment, thereby increasing nutrient levels, total solids, and decreasing water transparency. These consequences directly affect the reservoir ecosystem, which has a varying water level throughout the year. The water level in Tucuruí reservoir is characterized by four distinct periods: rising (December–February); high (March–May); falling (June–August) and low (September–November) (Eletronorte, 2016). Main characteristics of the Tucuruí reservoir are in Table 1 and the water level along 2014 in Fig. 2a.

We conducted the experiment at a single site (Caraipé 1) in one day each season. The Caraipé 1 is located at the main water mouth of the Amazonian SDR (03°50′03.4″ S to 49°42′32.10″ W). It is characterized by shallower waters and longer residence time comparing to the whole reserve and reservoir due to its dendritic morphology. Furthermore, dendritic edges and several islands around Caraipé 1 contribute to the increase of organic matter production due to water level fluctuation (Espíndola et al., 2000). Ecosystems with long residence time usually present high density and diversity of phytoplankton (Esteves, 2011).

2.2. Material

Samplings were performed during two seasonal periods: rainy (June 2014 – the falling phase of the Tucuruí