# Occurrence of *Ceratium furcoides* (Levander) Langhans 1925 bloom at the Billings Reservoir, São Paulo State, Brazil

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(With 2 figures)

## Abstract

An unusual bloom of *Ceratium furcoides* is reported for a station of the Taquacetuba compartment of the Billings Reservoir. The appearance of this bloom is attributed to the mixing and turbulence of the water column that removed *Ceratium* cysts from the surface of the sediment and promoted conditions for the growth of this species in the region of mixing. Cold fronts approaching the Billings Reservoir are probably the cause of the mixing and bloom. Also turbulence induced by wind increased phosphorus concentration in the water column. *Ceratium furcoides* was the dominant species at station 1 where the nutrient concentrations of nitrogen and phosphorus were high. *Ceratium* spp. blooms may be a problem for water treatment and massive mortality can affect the dissolved oxygen of the water producing fish kill.

*Keywords: Ceratium furcoides*, blooms, turbulence, cysts, cold fronts.

## Ocorrência de floração de *Ceratium furcoides* ( Levander) Langhans 1925, na represa Billings, Estado de São Paulo, Brasil

## Resumo

Neste trabalho, apresenta-se e discute-se a formação de florescimento de *Ceratium furcoides* no compartimento Taquacetuba da Represa Billings. Este florescimento é provavelmente resultado de intensa mistura vertical de coluna de água na região de transição entre este compartimento e o corpo central da represa. Esta mistura vertical é resultado do efeito de frentes frias sobre o sistema, promovendo interfaces que favorecem o aumento acentuado de fósforo na região do florescimento e o rápido crescimento de *Ceratium furcoides*. A turbulência gerada pode ter removido cistos da superfície do sedimento, promovendo o rápido crescimento desta espécie. O florescimento de espécies de *Ceratium* spp. pode ser problemático para o tratamento de água, pois pode causar depleção de oxigênio dissolvido após a decomposição, comprometendo a qualidade da água e aumentando os custos do tratamento.

Palavras-chave: *Ceratium furcoides,* floração, turbulência, cistos, mistura vertical.

## 1. Introduction

The occurrence of phytoplankton blooms in many eutrophic reservoirs of the world has been observed, as with genera of the Cyanophyta group, such as *Microcystis, Anabaena, Cylindrospermopsis* in some reservoirs. Another phytoplankton group, Dinophyta and the genus *Ceratium* bloom, has been registered. *Ceratium*'s genera is normally found in waters rich in nutrients, especially phosphate and nitrate and usually in association with Cyanophyceae (Lund et al., 1965). Blooms of *Ceratium hirundinella* has been recorded in several standing freshwater bodies of the world, such as in Hartbeespoort Dam in South Africa by van Ginkel et al., 2001, in a large enclosure located in lake Biwa, Japan by Nakano et al., 1999. Nevertheless, *Ceratium furcoides,* a very similar species to *Ceratium hirundinella,* was recorded at first time in the hydroelectricity power plant at Furnas Reservoir, MG, Brazil, by Santos-Wisniewski et al., 2007.

The present work shows the occurrence of *Ceratium furcoides* on the Billlings's Reservoir (Braço Taquacetuba) for the first time. This urban reservoir, especially constructed for energy generation and supplying water, receives substantial quantities of domestics and industrial sewage, causing the deterioration of water quality and changing these systems to hipereutrophic systems. With this increase of nutrients, there are favourable conditions for the growth of some phytoplankton groups.

For a long time, the dominant phytoplankton community on the Billings Reservoir was Cianophyceae, according to Carvalho et al. (2007), and many articles on the phytoplankton of the Billings Reservoir described the transformation occurring in these water bodies including the development of Cyanophyta such as *Microcystis, Planktothrix* and *Cylindrospermopsis.* These authors related, over the last decade, frequent occurrences of Cyanophyta blooms with occurrences of the same genera previously cited.

## 2. Material and Methods

Limnological studies were carried out on August 19th and 20th of 2008, in the Taquacetuba compartment of Billings Reservoir at the stations St1 (coordinates: 23° 48' 26.73" S and 46° 37' 30.41" W), St2 (coordinates: 23° 49' 32.90" S and 46° 37' 57.69" W) and St3 (coordinates: 23° 50' 36.39" S and 46° 39' 20.89" W).

Figure 1 shows the map of Billings Reservoir with the Taquacetuba compartment and the location of the three stations sampled.

At each station, local depth, temperature, pH, dissolved oxygen and conductivity were measured using multiparametric sensors. Also, water samples were collected at the surface and other depths in order to measure Chlorophyll-*a*, dissolved inorganic phosphate, nitrate, total phosphorus and total nitrogen.

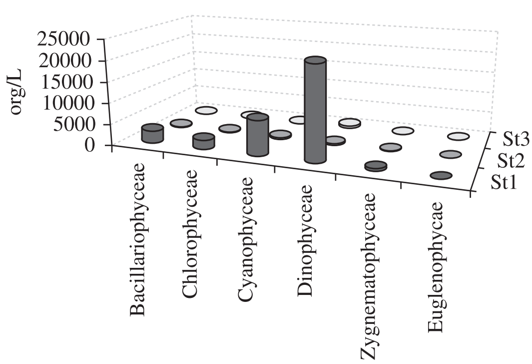


**Figure 1.** Density (nº org./L) of different classes of phytoplankton occurred in stations St1, St2 and St3 of Taquacetuba compartiment of Billings Reservoir, SP, during August, 2008.

The phytoplankton samples were collected by vertical hauls using a plankton net with 20 µm of aperture and the concentrate material was fixed with formalin solution 4%. Qualitative and quantitative analyses of different groups were carried out by optic microscopy (Leica DMLB German), using a Sedgwick Rafter Counting Chamber with zoom of 200× and a subsample of 1.0 mL. The bibliography used for phytoplankton identification was Bicudo and Menezes (2005), Bourrelly (1968), Komarek (1991), Mizuno (1964), Prescott (1966) and Streble and Krauter (1987).

## 3. Results

The Billings Reservoir has several compartments such as Taquacetuba and Riacho Grande where the limnological characteristics of the waters are quite different from the main compartment of the reservoir that receive a large quantity of sewage coming from the metropolitan region of São Paulo. Therefore, the phytoplankton community is different showing Cyanophyta blooms of *Microcystis aeruginosa* at all times. In the Riacho Grande compartment, studies performed by Matsumura-Tundisi et al., 2002, did not detect any occurrence of phytoplankton blooms.

At the Taquacetuba compartment, three stations were studied: St1 located near the main compartment of the reservoir, St2 in the middle part, and St3, at the end of the compartment near the entrance of the tributaries.

Table 1 shows the main physical and chemical variables measured at St1, St2 and St3 of Taquacetuba compartment of the Billings Reservoir.

As can be seen in Table 1, St1 presents higher concentrations of dissolved inorganic phosphate, nitrate and total phosphorus than St2 and St3. Dissolved oxygen and pH at the surface were very high, probably due to photosynthesis that can be seen by the high chlorophyll concentration presented at this station.

### *3.1. Phytotplankton communities and the Ceratium furcoides bloom*

The phytoplankton bloom observed at station 1 (Figure 1) was due to the Dinophyceae with the growth of the *Ceratium furcoides* population. This species is very similar

**Table 1.** Limnological data at stations St1, St2 and St3 of Taquacetuba compartment of Billings Reservoir (SP).

| Stations | St1 | | St2 | | St3 | |
|---|---|---|---|---|---|---|
| Local depth (m) | 10.0 | | 5.5 | | 5.5 | |
| Variables | Max | Min | Max | Min | Max | Min. |
| Temperature (ºC) | 21.75 | 19.01 | 21.73 | 18.6 | 21.63 | 19.0 |
| pH | 9.26 | 8.44 | 8.15 | 7.96 | 7.29 | 6.90 |
| Conductivity (µS/s) | 285 | 275 | 260 | 249 | 247 | 238 |
| Dissolved oxygen (mg/L) | 11.86 | 7.87 | 7.84 | 2.60 | 8.02 | 6.84 |
| Chlorophyll (µg/L) | 186.6 | 59.79 | 12.32 | 9.18 | 13.01 | 5.22 |
| Dissolved inorg. phosphate (µg/L) | 11.47 | 5.07 | 2.53 | 1.87 | 4.47 | 2.13 |
| Nitrate (mg/L) | 2.81 | 1.93 | 2.55 | 1.47 | 1.87 | 1.14 |
| Amonium (NH4) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total phosphorus (µg/L) | 140.45 | 72.0 | 26.0 | 19.0 | 26.0 | 24.0 |
| Total nitrogen (mg/L) | 3.99 | 1.27 | 4.58 | 0.14 | 0.91 | 0.09 |

to *Ceratium hirundinella*; however, it has some differences pointed out by Santos-Wieniewski et al., 2007. Figure 2 shows the general aspects of *Ceratium furcoides* obtained by image capture in the microscope, for the dorsal side (a), ventral side (b) and the schematic representation of the disposition of the plates at the dorsal valve (c) and the ventral valve (d).

According to Santos-Wieniewski et al., 2007, the main difference between the two species is the apical plates tabulation. *C. hirundinella* have 4 apical plates reaching the apex while in *C. furcoides,* 3 apical plates reach the apex and the 4$^{th}$ does not reach the apex.

Table 2 shows the phytoplankton composition and its density (n.org/L) measured at the three stations of the Taquacetuba compartment of Billings Reservoir.

Besides the occurrence of the *Ceratium furcoides* bloom, the St1 was characterised by the presence of Cyanophyceae, mainly the genus *Oscillatoria* and the presence of *Phacus*, Euglenophyceae characterising an environment rich in organic material.

## 4. Discussion

Reynolds (1997), when presenting theories and hypothesis related to the succession and development of phytoplankton populations in pelagic environments, emphasises the importance of the matrix of possibilities related to the distribution of downwelling irradiance and limiting nutrient concentration in relation to mixed depth represented by temperature distribution and algal growth supporting capacity. Therefore, the succession of phytoplankton in pelagic environments is dependent on the temporal organization of the vertical axis energy and nutrients. Disturbances in the pelagic populations represented by the appearance of large numbers of one species, as blooms, are attributed to sudden changes in vertical stability, depletion of nutrients and alterations in the underwater light climate. This is referred to by Reynolds (1997) as a "pulsed resource exploitation" resulting in a large population of a single species.

Episodes of the growth of massive populations of *Ceratium hirundinella* in Heart Lake, Ontario (Nicholls et al.,1980), Hartbeespoort Dam, South Africa (van Ginkel et al., 2001) have been reported. A fish kill in Heart Lake associated with a collapse of the massive population of *Ceratium hirundinella,* was reported by Nicholls et al. (1980).

*Ceratium furcoides* was reported in Furnas Reservoir (MG) as an invasive species by Santos-Wisniewski et al. (2007).

In Fetsui Reservoir, Taiwan, the abundance of *Ceratium furcoides* was positively correlated with phosphorus, total organic carbon, bacterial numbers and the biochemical oxygen demand in the water. According to Moya and Ramon (1984), cysts of *Ceratium* are found on the surface of the sediments. Thus the presence of these blooms can be attributed to the presence of resistance forms in the sediments of Billings Reservoir. These resistance forms were removed by the mixing effect.

*Ceratium furcoides* was dominant over other genera of phytoplankton at Station 1. In the Taquacetuba branch, very high phosphorus concentration occurred at this station. Station 1 is located in a region of mixing of waters from the main compartment of Billings Reservoir and the Taquacetuba branch.

As Demers and Legendre (1981) pointed out, mixing of two water masses can destabilise the water column favouring the replenishment of the surface layer in nutrients and removing the surface of the sediments thus promoting

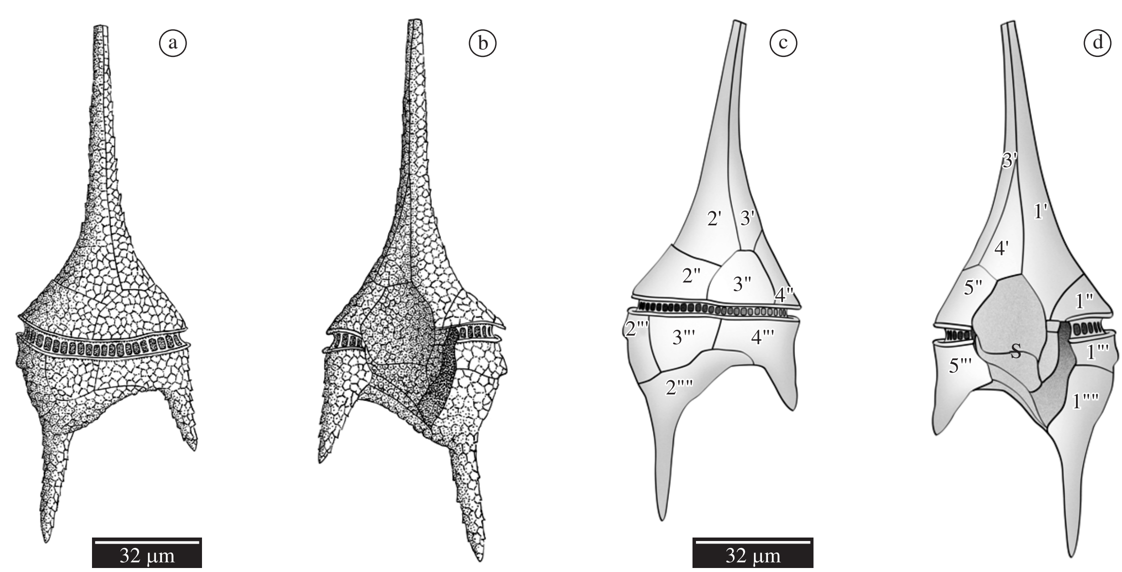


**Figure 2.** General aspects of *Ceratium furcoides*: (a) dorsal view; (b) ventral view; schematic representation of the disposition of the plates at the dorsal valve (c) and the ventral valve (d).

**Table 2.** Phytoplankton composition and its density ($n^0$ org./L) in the Taquacetuba compartment of Billings Reservoir in São Paulo State.

| Sampling stations | St1 | St2 | St3 |
|---|---|---|---|
| **Data** | **19/08/2008** | **19/08/2008** | **19/08/2008** |
| BACILLARIOPHYCEAE | | | |
| *Fragillaria* | 15570 | 0 | 0 |
| *Asterionella* | 311394 | 11121 | 3244 |
| *Aulacoseira* | 2692144 | 297493 | 9731 |
| CLHOROPHYCEAE | | | |
| *Asterococcus* | 77849 | 0 | 0 |
| *Botryococcus* | 31139 | 5561 | 0 |
| *Chlorella* | 373673 | 77849 | 12975 |
| *Chlorococcum* | 186837 | 91750 | 74605 |
| *Coelastrum* | 15570 | 0 | 0 |
| *Dictyosphaerium* | 155697 | 11121 | 0 |
| *Desmodesmus* | 15570 | 0 | 0 |
| *Kirchineriella* | 358103 | 69508 | 6487 |
| *Micractinium* | 591649 | 30583 | 3244 |
| *Oocystis* | 15570 | 5561 | 3244 |
| *Pediastrum* | 171267 | 38924 | 19462 |
| *Radiococcus* | 15570 | 5561 | 0 |
| *Scenedesmus* | 217976 | 13902 | 16218 |
| *Selenastrum* | 15570 | 11121 | 0 |
| CYANOPHYCEAE | | | |
| *Anabaena* | 15570 | 5561 | 0 |
| *Chroococcus* | 404812 | 100091 | 64874 |
| *Microcystis* | 186837 | 13902 | 0 |
| *Oscillatoria* | 7753715 | 467091 | 74605 |
| DINOPHYCEAE | | | |
| *Ceratium* | 21455060 | 544940 | 535209 |
| *Peridinium* | 1027601 | 38924 | 19462 |
| ZYGNEMATOPHYCEAE | | | |
| *Closterium* | 15570 | 116773 | 3244 |
| *Closteriopsis* | 77849 | 2780 | 0 |
| *Mougeotia* | 529370 | 88970 | 38924 |
| Staurastrum | 62279 | 5561 | 0 |
| EUGLENOPHYCEAE | | | |
| *Hyalophacus* | 0 | 2780 | 0 |
| *Phacus* | 46709 | 0 | 0 |

the development of phytoplankton blooms, in this case *Ceratium furcoides.*

Nutrient concentration in these mixed layers can be very high and phytoplankton appears to respond rapidly to these charges as pointed out by Legendre (1981).

Further evidence of the mixing effect on the appearance of the blooms of *Ceratium furcoides* is the effect of the cold fronts on the vertical mixing of the water column at station 1. Before the occurrence of the bloom, a cold front was approaching from the southern region to São Paulo State. Tundisi et al. (2010 in press) demonstrated that wind velocity is higher during the days immediately before the cold front promoting mixing in the water column. Turbulence is maintained during the passage of cold fronts.

Episodes of vertical mixing and changes in the structure of the water column associated with the passage of cold fronts were described by Tundisi et al. (2004), for the UHE Carlos Botelho (Lobo/Broa) reservoir. These episodes explain the changes in the succession of phytoplankton associated with the periods of stratification and mixing of the water column (Lund, 1965).

*Ceratium furcoides* blooms can be harmful to fishes due to decomposition and oxygen depletion after the collapse of these massive populations. But also it can be a problem for water treatment. Since the Taquacetuba branch of the Billings Reservoir has its water used for public supply, a more accurate sampling program for detection and follow up of further occurrence of these blooms is required.

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