Lakewide odours in Ontario and New Hampshire caused by *Chrysochromulina breviturrita* Nich. (Prymnesiophyceae)

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Abstract

At densities of 500–9 000 cells/ml, the planktonic alga *Chrysochromulina breviturrita* Nich. produced obnoxious lake-wide odours in five lakes between 1978 and 1980. In one case, $CuSO_4$ was used to kill the organism and control the odour, but in the other four lakes, the species persisted for 4–6 weeks before populations declined and odours disappeared. This is the first recorded instance of odour production by any member of the Prymnesiophyceae.

Introduction

Odours from freshwaters are derived from a variety of biological sources (Silvey 1966; Persson 1981) but can be generally categorized into two groups: odours originating from the decomposition of organic material and those produced by living cells.

Odours, described as fishy, grassy, aromatic or musty, have been attributed to the growth of several species of planktonic algae (Palmer 1962; Maloney 1963; Jayangoudar & Ganapati 1965; Taft 1965). Some species are toxin producers and have caused sickness and death in mammals and fish (Schwimmer & Schwimmer 1968). No member of the class Prymnesiophyceae (sensu Hibberd 1976) is a known odour producer, although *Prymnesium parvum* Carter is toxic to fish (Shilo 1964; Holdway *et al.* 1978). Several species of *Chrysochromulina* are closely related to *Prymnesium* (Manton & Leedale 1963; Pienaar & Norris 1979), but only two (*C. birgeri* Hällfors et Niemi and *C. parva* Lackey) are known to approach 'bloom' concentrations in the wild (Kristiansen 1971; Hällfors & Thomsen 1979). In this paper we report the apparently recent development of obnoxious lakewide odours associated with *Chrysochrumulina breviturrita* Nich. in Ontario and New Hampshire freshwater lakes and discuss some aspects of the occurrence of *C. breviturrita*.

Methods

Phytoplankton samples were collected weekly in Dickie Lake (79° 05′ W, 45° 05′ N), biweekly in Crosson Lake (79° 02′ W, 45° 05′ N) and biweekly and monthly in Cinder Lake (78° 56′ W, 45° 04′ N) in Ontario during 1976–80 with a peristaltic pump at a series of depths between the lake surface and a depth corresponding to twice the Secchi disc visibility. Samples were combined in a volume ratio proportional to the volume of the lake represented by each sampling depth interval to yield samples representing weighted composites of the euphotic zone. Samples from Austin Lake (78° 51′ W, 45° 07′ N) and Northwood Lake in New Hampshire (71° 15′ W, 43° 13′ N) were not collected regularly, but were obtained as surface or euphotic zone composites only after the odour problems were brought to our attention. Samples for determination of unweighted vertical distribution of *C. breviturrita* in

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Dickie Lake were collected with a tube designed for profile sampling (Nicholls 1979). Enumeration was at 600× with an inverted microscope and Utermohl-type counting chambers. Cell numbers were converted to cell volume after measuring cell size. Identification of specimens as *C. breviturrita* was by electron microscopy.*

Zooplankton samples were collected weekly during 1977 with a 34 l transparent trap (Schindler 1969) with attached 80 μm mesh and during 1978 and 1979 with a vertical tow net equipped with a calibrated flow meter. Sampling with both apparati was done through selected depths so that pooled samples representing the water column were obtained. Zooplankton counts were converted to dry weight using literature values or factors determined for other studies (R. Strus, personal comm.).

Samples of living material in lake water were returned to the laboratory for culturing, filtration experiments (activated charcoal and glass fiber) and toxicity testing (see text) at the laboratories of the Ontario Ministry of Health (Toronto) and the Ontario Ministry of Agriculture and Food (Guelph).

Observations and discussion

Chrysochromulina breviturrita was discovered in the plankton of Ontario lakes in 1977 and described as a new species (Nicholls 1978). Our first encounter with this organism in 'bloom' proportions was in July of 1978 in Northwood Lake, Rockingham County, New Hampshire. The State of New Hampshire Water Supply and Pollution Control Commission investigated complaints from many lake residents of an offensive 'rotten cabbage' odour. The odour clearly originated from the lakewater. Microscopic analysis of three surface samples showed an average density of 8 800 *C. breviturrita* cells/ml and a virtual absence of other species. The odour interfered with recreational use of the lake to the extent that a $CuSO_4$ treatment was necessary to destroy the algal infestation. The 280 ha lake was treated by bag dragging coarse-crystal $CuSO_4$ at 4.8 kg/ha assuming effective treatment of the upper 3 m of the lake (max. depth = 7.3 m). The odour had essentially disappeared two days after the algicide application. No fish mortalities associated with the *Chrysochromulina* bloom or the $CuSO_4$ treatment were observed.

In July of the following year (1979) obnoxious odours developed in two lakes in the Haliburton area of Ontario. Odours from both Dickie Lake (McLean Twp.) and Austin Lake (Hindon Twp.) were similarly described by summer residents as 'rotten cabbage', 'dead animal' and 'garbage dump' and were at times so strong that they were easily detected from the roadway well back from the lakeshore. Samples of lakewater showed almost unialgal populations of *C. breviturrita* in both lakes. The odour was so offensive that many people refrained from swimming and other lakeside recreational activities. Those who did swim and waterski found it necessary to bath and wash swimwear with strong soap to remove the odour.

According to Dickie Lake cottagers, the odour was most severe during the second and third weeks of July 1979 which corresponds with the maximum recorded biomass of *C. breviturrita* on July 20 (Fig. 1). The odour had begun to subside by the end of July. By mid-August, when biomass had declined to about 460 mm^3/m^3 (3 500 cells/ml), the odour was almost undetectable. By early September *C. breviturrita* had declined to insignificant densities (Fig. 1) and all traces of the odour were gone.

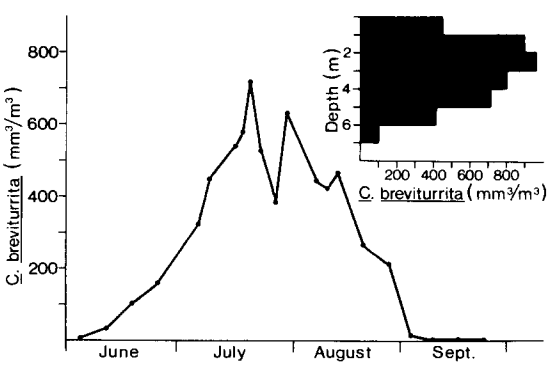

Fig. 1. The periodicity of *C. breviturrita* in Dickie Lake during the summer of 1979 and vertical distribution between the lake surface and 8 m on 28 July.

* Identification of this species must be confirmed by electron microscopy (EM) since unpublished work suggests that specimens with a single scale type [per Fig. 25 of Nicholls (1978)] might best be assigned to a separate species. The *Chrysochromulina* species responsible for odour production in all of the lakes in Ontario and New Hampshire was confirmed by EM to have the spined scales characteristic of *C. breviturrita*.

During the period of severe odour production, results of profile sampling in Dickie Lake suggests that *C. breviturrita* was present throughout most of the lake (Fig. 1); the 0.5 m portion of the water column represents approximately 75% of the total lake volume.

In Austin Lake, the worst period of odour had passed by 8 August 1979, when the first sample was collected for analysis; cell density was 190 mm^3/m^3 (2 100 cells/ml) and an odour was still noticeable.

C. breviturrita densities remained very low during the summer of 1980 in both Dickie and Austin Lakes and no odours were experienced. However, during August and September of 1980, odours developed from Crosson Lake (Oakley Twp.) and Cinder Lake (Hindon Twp.), Ontario. Neither lake had any occupied cottages or permanent residences but an Ontario Ministry of Natural Resources Junior Ranger station is located at Crosson Lake. As for the three previous lakes producing similar odours, the plankton of both Cinder and Crosson Lakes was dominated by *C. breviturrita* (Fig. 2). Odour from Crosson Lake during the third week of August was so offensive that participants in the Junior Ranger program would not swim in the lake. The odour persisted until the second week of September by which time *C. breviturrita* densities had declined from a maximum of 85 mm^3/m^3 (1 000 cells/ml) to <5 mm^3/m^3. On 11 September, the odour on Cinder Lake was very strong, with a cell density of 180 mm^3/m^3 (2 150 cells/ml).

Cottagers were annoyed and puzzled by the problem which, according to three long-time residents on Dickie Lake, was the first occurrence in their 18–20 years experience on the lake. Two summer residents for 25 years on Austin Lake said that they had never before experienced an odour problem on the lake. Ministry of Natural Resources staff could not recall a previous odour problem on Crosson Lake during the more than 15 years of administering the Junior Ranger station.

Although the time periods of severe odour were readily related to peak *C. breviturrita* density within a lake, it is difficult to relate *C. breviturrita* density to the intensity of odour among all lakes. Severe odours were associated with cell densities of approximately 3 000–9 000 cells/ml in both Northwood and Dickie Lakes. However, serious odour developed on Crosson Lake with densities of only 500–960 cells/ml.

Water temperature may be a very important factor governing odour production and release from lakewater. Surface water temperatures of all five lakes during odour production ranged between 18

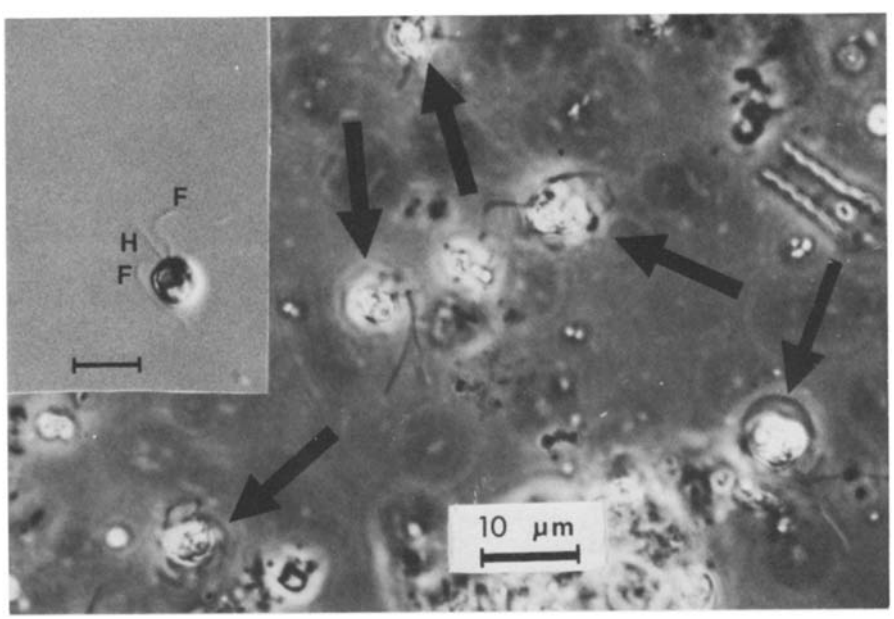

Fig. 2. Surface water sample from Cinder Lake showing domination of the plankton by *C. breviturrita* (11 Sept. 1980; concentrated by sedimentation in Lugol's iodine solution). Inset shows living cell with rigid haptonema (H) and two flagella (F).

and 25 °C. No one recalls an odour from Dickie Lake during early November of 1978 when water temperature was 5 °C and densities of *C. breviturrita* reached a maximum of 6 300 cells/ml, although few people were near the lake at that time of the year. Heating Cinder Lake water to boiling point changed the character of the odour to distinctively 'fishy'. The odour was retained on glass fiber filters (pore size <4 μm) and filtration through activated charcoal also removed the odour from lakewater.

The immediate questions and concerns arising out of these experiences are:

1. Is *C. breviturrita* a recent introduction and are its populations increasing in much the same way that its close relative *Prymnesium parvum* apparently spread through the Middle East in the 1940s and 1950s (Shilo & Shilo 1955).
2. Are subtle long-term changes occuring in the quality of Ontario and New England lakewaters which are conducive to massive development of this species?
3. Notwithstanding the obnoxious odours produced by *C. breviturrita,* could this species also be a toxin producer as is its close relative *P. parvum?*

Analysis of available data can only partly answer these questions at this time. The five lakes with odour production by *C. breviturrita* are all relatively small (<95 ha) and range in maximum depth from 7 to 25 m. Specific conductance (28–60 μhos/cm), colour (10–40 Hazen units), total nitrogen (300–500 μg N/l) and total phosphorus (8–13 μg P/l) levels are typical of many lakes on the Precambrian Shield. All five lakes are slightly acidic (pH, 5.5–6.2; alkalinity, 1–6 mg $CaCO_3$/l).

Alkalinity and pH data are available for most of the more than 40 lakes in Ontario where we have recorded *C. breviturrita.* There is a clear tendency for it to be found in softwater lakes. Of the lakes known to contain *C. breviturrita,* 60% have summer pH values from 5.9 to 6.9 and alkalinities from 1 to 10 mg $CaCO_3$/l. An additional 20% have pH and alkalinity values less than 5.9 and 1 mg $CaCO_3$/l, respectively. *C. breviturrita* has not been found in any samples from more than 100 lakes of southeastern and southern Ontario and lakes of the Bruce Peninsula with alkalinities between 100 and 280 mg $CaCO_3$/l.

Unfortunately, data or samples from none of the five lakes in Ontario and New Hampshire are available prior to late 1976, so it is not possible to determine if *C. breviturrita* was present in these lakes prior to 1976. Samples from Dickie Lake since lake 1976 show that *C. breviturrita* was present during each of the last four years; however, year-to-year seasonal development has been highly variable. The 1977 population was very small; the largest populations were found in the autumn of 1978 after being virtually absent for most of the summer (Fig. 3). In contrast, the 1979 summer population was large, but very low densities were found during the autumn. Zooplankton samples collected from late 1976 through August 1979 showed a marked reciprocal relationship between zooplankton biomass and *C. breviturrita* density (Fig. 3). Significant development of *C. breviturrita* may occur only when zooplankton density, and associated grazing pressure, is low.

The undesirable consequences of growth of *C. breviturrita* in lakes may not be restricted to odour production. Cottagers on Dickie Lake observed a die-off of tadpoles during the July 1979 *C. breviturrita* growth period. This observation might be important since tadpoles of *Bufo* and *Rana* spp. are especially sensitive to the toxin produced by *C. breviturrita's* close relative *Prymnesium parvum* (Shilo 1971). Results of two separate experiments in different laboratories suggest that *C. breviturrita* is not toxic to mice. A sample of Dickie Lake water collected 18 July 1979, retained in the laboratory for several weeks and supplemented with a dilute nutrient medium (Tompkins & Blinn 1976) served as the source of inoculum for two toxicity experiments. In the first experiment, begun on 1 August, three laboratory white mice received an intraperitoneal injection of 0.5 ml centrifuged culture solu-

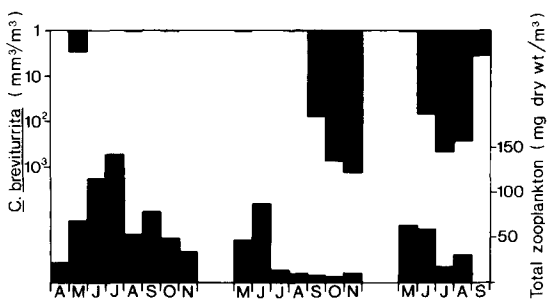

Fig. 3. Monthly average biomass of *C. breviturrita* (cell volume) and total crustacean zooplankton (dry wt.) in Dickie Lake between 1976 and August 1979.

tion containing 7×10^4 *C. breviturrita* cells/ml and were given *C. breviturrita* in drinking water at a concentration of 4 500 cells/ml. A control group of three mice was injected with 0.5 ml of distilled water and given 'normal' drinking water. In the second experiment, begun on 15 August, 12 mice were divided into four groups of three mice each. Group 1 was injected (intraperitoneally) with 0.25 ml of culture containing 1.5×10^4 cells/ml on 15 and 16 August. Group 2 was treated as for group 1, except that a bacteria-free filtrate of the sample was used for injection. Group 3 received water to drink, ad libitum, containing 1.5×10^4 cells/ml. Group 4 served as a control.

There were no apparent ill affects to mice by 10 August in the first experiment or by 18 August in the second experiment. Nevertheless, all toxicity implications should probably not be dismissed since toxicity of *Prymnesium parvum* cultures is often markedly different from natural populations (Shilo 1971), and the same may be true of *C. breviturrita* if it is a toxin producer. Bioassays with frog tadpoles and fish would be necessary to determine if *C. breviturrita* produces an ichthyotoxin.

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