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Paleolimnological investigation of the effects of road salt seepage on scaled chrysophytes in Fonda Lake, Michigan

Barbara A. Zeeb & John P. Smol
Department of Biology, Queen's University, Kingston, Ontario, K7L 3N6, Canada

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Abstract

Chrysophyte scales were identified and enumerated from the recent sediments of Fonda Lake, Michigan. This lake has undergone marked salinification due to chloride intrusion from an adjacent salt-storage facility established in 1953. From 1950 to 1980, *Mallomonas caudata* dominated at all levels; this taxon appears to be chloride-indifferent. *M. elongata* and *M. pseudocoronata* appeared to be chloride-intolerant as they declined drastically in abundance when chloride levels attained a maximum (*ca.* 1968–1972). *M. tonsurata*, on the other hand, was more competitive during this period of maximum [Cl^-]. This preliminary study suggests that chrysophyte scales may be useful paleoindicators of salinity.

Introduction

Fonda Lake, Michigan, is a discharge seepage lake that has undergone a striking increase in lakewater salinity since 1953 when a salt storage facility was established adjacent to the lake. Tuchman *et al.* (1984) conducted a paleolimnological analysis of the diatoms in this lake and found that shifts in diatom taxa were related to salinification.

In this study, we identify the chrysophyte scales found in the same Fonda Lake core, and report on the effects of increased salt concentration on this assemblage. Paleolimnological investigations using chrysophyte scales have now been used in studies dealing with lake eutrophication and acidification (e.g. Battarbee *et al.*, 1980; Smol *et al.*, 1983; Smol, 1986; Siver, 1989); however, to our knowledge, scales have never been directly used in studies of lake salinification. Individual taxa are tentatively identified as chloride-indifferent, chloride-tolerant, or chloride-intolerant, based on their stratigraphic distributions in the core.

Study site

Fonda Lake is located in Livingston County, Michigan. The lake is spring fed, has no permanent inlet or outlet, and has a maximum depth of 13 m. According to a 1951 study, the pH ranged from 7.2 to 8.6 (Michigan DNR, unpub. data). The average chloride concentration in 1981 was 235 mg l^{-1} throughout the water column, whilst typical values for lakes in the area were approximately 12 mg l^{-1} (Frains Lake) and 15 mg l^{-1} (Portage Lake). The elevated chloride concentration in Fonda Lake was due to runoff and leaching from a salt storage facility (built in 1953) located adjacent to the lake.

Tuchman *et al.* (1984) used cluster analysis to delineate five diatom zones. The bottom of the core, or Zone 1, representing *ca.* 1948–1952, was characterized by a benthic alkaliphilous, chloride-indifferent diatom flora. In Zone 2 (*ca.* 1954–1960) the flora had a more planktonic composition, but remained chloride-indifferent. Zone 3 (*ca.* 1962–1966) was characterized by a decrease in diatom species diversity and evenness, possibly indicating the initial effects of salt loading into the lake 9 years after the placement of the salt storage shed. Unfortunately, no chloride values are available for this period, or any earlier periods. In Zone 4 (*ca.* 1968–1972) chloride concentrations appear to have reached a maximum, and halophilic diatom species peaked in abundance. Tuchman *et al.* indicate that chloride concentrations have decreased during Zone 5 (*ca.* 1974–1980) due to the construction of an asphalt pad for the salt-storage facility in the early 1970's. They suggest that chloride levels attained a maximum in the late 1960's and early 1970's, and have since decreased (although not to pre-influence levels) and remained relatively constant.

Materials and methods

A 20 cm core was taken from the profundal sediments of the lake on February 17, 1981 with a Shapiro (1958) freeze corer. The frozen sediment on the outside of the core barrel was sectioned at 1 cm intervals in the laboratory. This study reports on the stratigraphic distribution of scales from the upper 15 cm of the core.

Due to their silicious nature, chrysophyte scales can be studied using the same digestive and microscopic techniques used for fossil diatoms. In this study, we used the identical strewn mounted slides prepared by Tuchman *et al.* (1984). Scales were identified and enumerated using oil immersion (1250 × magnification) on a Nikon Optiphot microscope equipped with phase contrast optics. Chrysophycean scales were counted along parallel transects at each 1 cm interval in the core. Due to low scale density and the low number of taxa, only 100 scales were enumerated at each depth.

Scanning electron microscopy (SEM) was used to confirm the taxonomic identifications. SEM stubs were prepared by evaporating sediment slurries onto aluminum foil and mounting the foil onto aluminum SEM stubs using double-sided adhesive tape. Each stub was coated with *ca.* 20 nm of gold using a Polaron Instruments Sputter Coater. Scanning electron micrographs were taken using a Hitachi-S-450 SEM.

The core was Cesium-137 dated by Tuchman *et al.* (1984) according to the method of Robbins & Edgington (1975). According to their analysis, the 15 cm depth corresponds to *ca.* 1950 and each successive year is represented by approximately 0.50–0.55 cm of sediment, such that 1980 (the year preceding core collection) is reached at the top of the core.

Results and discussion

Chrysophyte scales were well preserved; however the 30 year period represented by the core was found to be poor in taxa, with only 4 *Mallomonas* species dominating the assemblage. Other taxa were present (mainly *Synura* spp.), but only at trace levels, and were grouped into the collective category 'Other' (Fig. 1).

Mallomonas caudata dominated the assemblage at all depths (65–80% abundance), and therefore we tentatively suggest that it is chloride-indifferent. This ecological interpretation is consistent with other ecological data, as it is common and widely distributed, particularly in circumneutral and alkaline waters (Nicholls, 1982; Smol, 1986), including lakes with high conductivities (Siver & Hamer, 1989).

M. elongata may be extremely sensitive to high [Cl^-], as it disappeared completely at 10 cm (*ca.* 1960), and did not subsequently recolonize the lake despite the decline in salinity indicated by diatoms. This taxon is widely distributed (Nicholls, 1982), but is most common in more eutrophic and alkaline waters. Similarly, *M. pseudocoronata* declined strikingly near 10 cm (*ca.* 1960), and reached its lowest abundance at 3–5 cm (*ca.* 1970–1974), when the lake was

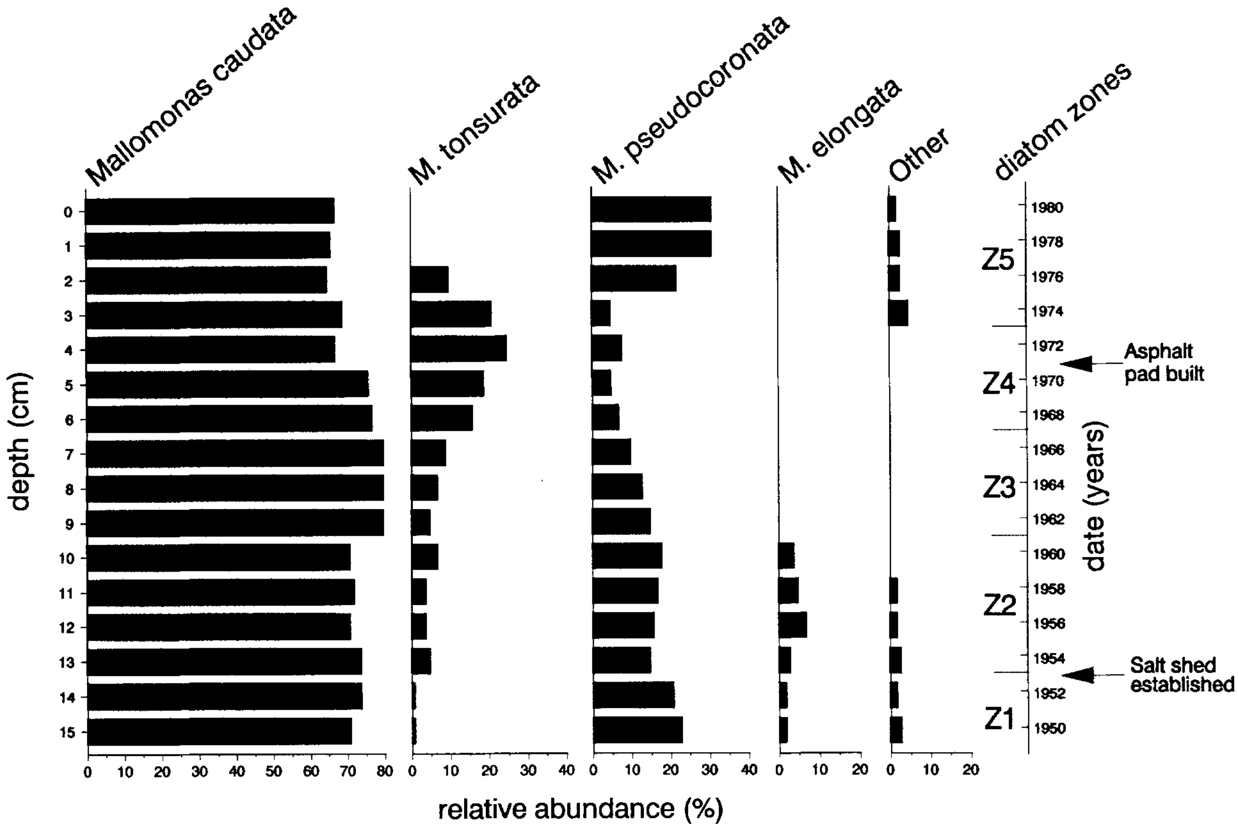

Fig. 1. Relative abundances (%) of chrysophyte scales identified in the top 15 cm of a core from Fonda Lake, Michigan. Diatom zones (Z1–Z5), as described by Tuchman *et al.* (1984), are shown to the right. Collective category 'Other' is comprised mainly of *Synura* spp.

presumably at maximum salinity (Tuchman *et al.*, 1984). *M. pseudocoronata* increased again in abundance as salinity declined. The marked declines in abundance of these two species occurred near the transition of Zones 2 and 3 (Fig. 1). This is consistent with the distribution of Group 2 diatoms described by Tuchman *et al.* (1984). We tentatively interpret these 2 species changes as a result of salinification, although we know of no other ecological data to support our speculations.

Coincident with the decline of the chloride-intolerant chrysophyte species, *M. tonsurata* increased in relative abundance (Fig. 2). This taxon reached maximum abundance (25%) at 4 cm (*ca.* 1972), and thereafter decreased rapidly, and completely disappeared near the top of the core (*ca.* 1978). Previously, this species has been described as having a world-wide distribution, occurring mainly in eutrophied lakes and ponds (Hartmann & Steinberg, 1989). This taxon has been classified as alkaliphilous, and several workers (Kristiansen, 1986; Smol *et al.*, 1983; Smol & Boucherle, 1985) have recorded it in lakes with pH > 8.0. Based on our present study, *M. tonsurata* remains competitive with high salt concentrations, analogous to the halophilic Group 4 diatom taxa described by Tuchman *et al.* (1984).

Conclusions

In this preliminary study, we have attempted to infer stratigraphic changes in the relative abundances of chrysophyte scales to changes in lake-water salinity. Similar to the Tuchman *et al.* (1984) diatom study, the greatest changes in percent abundances of chrysophyte scales are exhibited by the sub-dominant taxa. *Mallomonas* caudata dominates the core and would seem to be chloride-indifferent, *M. elongata* and *M. pseudocoronata* appear to be chloride-intolerant, whereas *M. tonsurata* appears to be chloride-tolerant and possibly a halophile. Further work should quantify the optima and tolerances of these and other taxa using gradient analysis and surface sediment calibration sets. Should scaled chrysophytes be shown to be sensitive markers of lakewater salinity, these data may potentially be important in future studies of climatic change, where stratigraphic changes in taxa in closed-basin saline lakes may be used as proxies of past climate (Fritz & Battarbee, 1988).

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