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Bryozoan statoblasts in the recent sediments of Douglas Lake, Michigan

Donna R. Francis
Center for Great Lakes and Aquatic Sciences, University of Michigan, Ann Arbor, MI 48109-2099, USA

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Abstract

Statoblast valves produced by the freshwater bryozoan *Plumatella nitens* were recovered in three sediment cores from Douglas Lake, Michigan. Douglas Lake is a multi-depression lake of glacial origin. The region was heavily logged from 1880 to 1920. Sediment cores were taken from three of the seven depressions, and dated using ^{210}Pb isotopes and pollen. Sedimentation rates were very low in the Grapevine Point core as compared to the other two cores. Concentrations of statoblasts ranged from three to 140 ml^{-1} of wet sediment. Profiles of statoblast concentrations and accumulation rates indicate a sharp decline in *Plumatella* populations corresponding to the time the Douglas Lake watershed was being clear-cut. It appears that logging and the resulting increase in erosion had adverse effects on bryozoan populations, and possibly on the entire littoral zone of the lake. High sediment loads to the lake could have caused mortality in *Plumatella* by interfering with the feeding of these animals, or by decreasing numbers of macrophytes which are frequently used as substrate. Populations of *Plumatella* have not recovered to pre-disturbance levels.

Introduction

Freshwater members of the phylum Bryozoa are sessile animals that grow on underwater surfaces and produce resistant overwintering structures called statoblasts (Pennak, 1989). Statoblasts, of which there are several types, are constructed of two chitinous valves that resist decay when buried in sediments. Bryozoans are littoral zone dwellers, usually in water less than ten meters deep (Pennak, 1989), and macrophytes are a common substrate for many species. Bryozoan statoblasts were mentioned as potential paleolimnological tools by Frey (1964). However, very little use has been made of them in this regard. Stahl (1959) reported numbers of *Plumatella* sp. statoblasts ranging from zero to 63 ml^{-1} sediment in a core from Myers Lake, Indiana. Unfortunately, statoblasts were counted in only seven intervals of this core, and no interpretations of change in abundance were possible.

Recent work on the surface morphology of statoblasts has shown that surface features are taxonomically significant, and may prove more useful than colony morphology (Reynolds, 1995). This will be important in paleolimnological studies since the statoblast valves are the only remains of the animals found in sediments, and they can be identified to the species level.

It has been suggested that statoblast accumulations may be indicative of either phytoplankton biomass or macrophyte development in the littoral zone (Crisman et al., 1986). In a survey of surficial sediments from 30 Florida lakes, Crisman et al. (1986) found correlation between these two parameters and statoblast accumulation. Dendy (1963) also noted correlation between *Plumatella* growth and the fertility of experimental farm ponds in Alabama. Other factors that may affect bryozoan populations include water temperature, pH, and degree of siltation (Pennak, 1989). Silting discourages bryozoans, presumably because it interferes with feeding. They are never associated with severe pollution, low dissolved oxygen, or low pH (Pennak, 1989).

Study site

Douglas Lake (45° 35′N, 84° 41′W) is a multi-depression lake of glacial origin in the northern lower peninsula of Michigan, U.S.A. with seven separate basins (Figure 1). The total area of Douglas Lake is 1509.4 ha, maximum depth 27 m, mean depth 5.5 m, and volume 8.3×10^7 m^3. Area of the drainage basin is 5650 ha. The differences that exist among these basins have been the subject of much interest to limnologists working at Douglas Lake since 1909 at the University of Michigan Biological Station. Differences in chemical and physical parameters and biota among the depressions have been documented many times (Welch, 1927; Eggleton, 1931; Welch & Eggleton, 1932; Campbell, 1941; Welch, 1944), with each depression behaving somewhat like an independent lake (Welch, 1927). Welch noted differences in onset and duration of thermal stratification, hypolimnetic temperatures, and chemistry. Eggleton (1931) and Campbell (1941) found differences in profundal benthic communities and distributions of rotifers in the basins.

The history of settlement in the Douglas Lake region has been reviewed by Kilburn (1957), in a study of vegetation changes in Cheboygan County. The first recorded European settler arrived in 1845. The population increased to over 2000 by 1870, and reached a peak of 17 872 in 1910. Farms were established in areas of loamy soils, but the greatest draw to the area was the stands of red and white pine, hemlock, and hardwood forests. The first sawmill was established in 1846, but lumber production probably reached its peak of 200 million board feet in 1896 when there were sixteen sawmills in the county. By 1900, conifers in the area were gone, and the hemlock-hardwood forests were then logged, until about 1920 (Kilburn, 1957).

During the lumbering period, there were also many fires, which kept aspen and other timber from becoming re-established (Kilburn, 1957). The occurrence of frequent fires between the years 1880 and 1923 are corroborated by the testimony of local residents, early workers at the Biological Station, and fire scars on red pine stumps (Kilburn, 1957). Fires ceased after the 1920s with establishment of fire control measures. The timing of pine and hardwood logging, along with fires, was also documented by botanists working at the biological station (Gates, 1912; Gleason & McFarland, 1914). Vegetation that replaced the pines included aspens (*Populus* spp.), birch (*Betula* spp.) and fire cherry (*Prunus pensylvanica*), with abundant bracken fern (*Pteridium aquilinum*) and bush honeysuckle (*Diervilla lonicera*) on the forest floor (Gates, 1912). Aspens also became established in areas where hardwoods were logged, but did not remain dominant.

Statoblasts were present in three cores from three different basins of Douglas Lake. The stratigraphy is reported here in hopes that it will contribute both to the understanding of the historical events in Douglas Lake, and the general usefulness of statoblasts as paleolimnological indicators.

Materials and methods

Cores were collected through ice cover in March 1989 (Figure 1) using a Benthos Corp. gravity corer with a 6.7 cm diameter Lexan core tube, modified with a rubber piston. Cores were extruded immediately and sectioned at 1 cm intervals. Each interval was placed in a plastic bag and stored at 4 °C. Bryozoan statoblasts were counted in the same samples prepared for chironomid analysis. Preparation followed the methods of Walker (1987). Two to five ml of wet sediment was transferred to a beaker and treated with 10% HCl overnight at room temperature. HCl was removed from the sample by rinsing through a 100 μm Nitex sieve. The sample was then treated with 5% KOH on a warm hotplate for 20 min, and again rinsed through a 100 μm sieve. Samples were sorted under a stereomicroscope at 50 × using a Bogorov counting chamber (Gannon, 1971). All statoblast valves in the sample were counted. Statoblasts were removed and stored in 70% EtOH for identification.

Profiles of statoblast abundance were plotted using the computer programs TILIA and TILIA-GRAPH, developed by E. C. Grimm, Illinois State Museum Research and Collections Center. Sediment cores were dated using ^{210}Pb isotope dating and pollen profiles (Francis, 1995). Dates and sedimentation rates were calculated using a CRS point transformation model (Binford, 1990). Sedimentation rates below the level of unsupported ^{210}Pb were estimated using rates at the lowest dated levels, and were assumed to be constant. Accumulation rates of statoblast valves were calculated by multiplying valve concentration by the sedimentation rate for each interval.

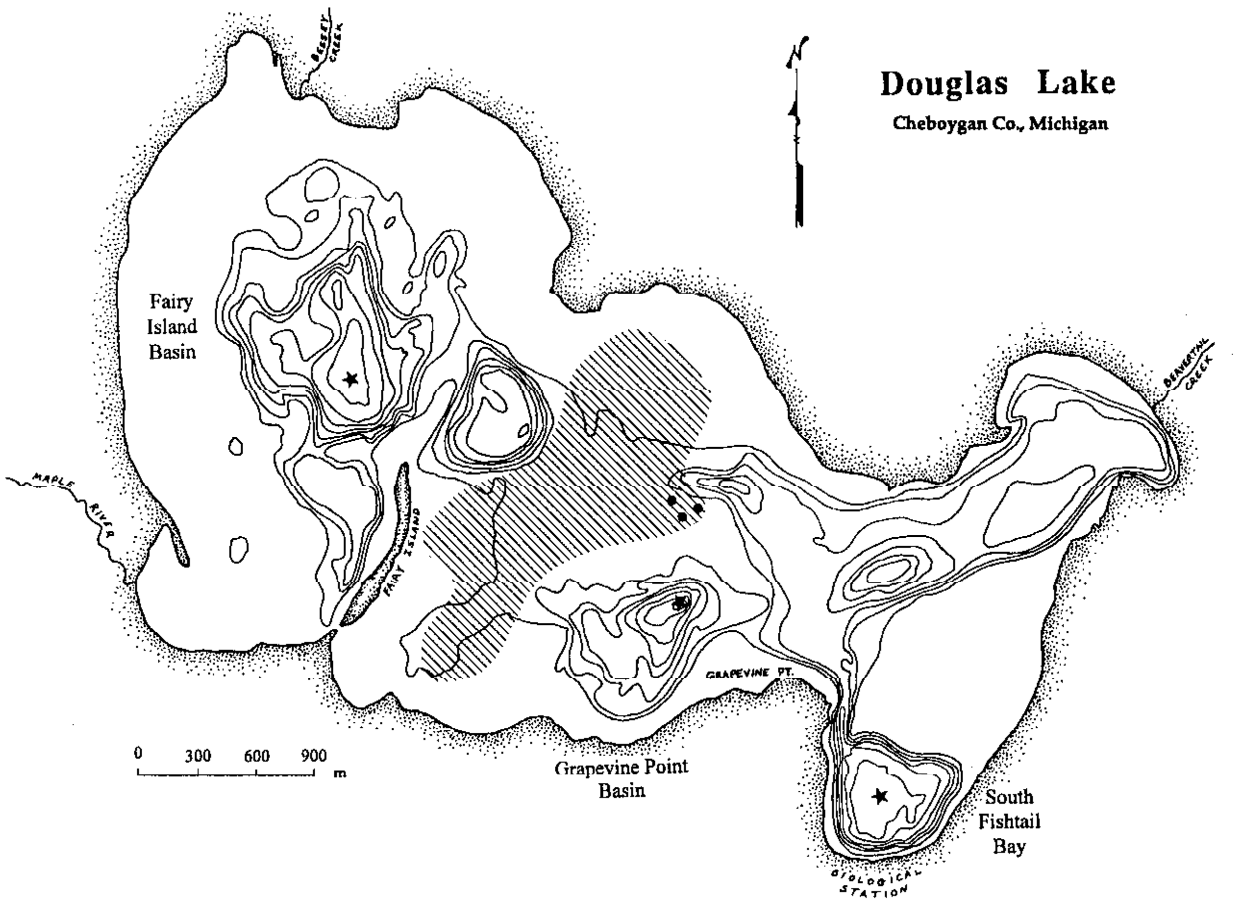

Figure 1. Bathymetric map of Douglas Lake, Michigan, U.S.A. Contour interval = 3 m. Stars indicate coring sites. The cored basins are named, left to right: Fairy Island basin, Grapevine Point basin, and South Fishtail Bay basin. Shading indicates the area studied by Eggleton (1952), in which *Plumatella* colonies were recorded from stations indicated by closed circles.

Results and discussion

Although concentrations of statoblasts are reported to be low in the sediments of many lakes (Walker, 1993), they were quite abundant and easily counted in all three cores from Douglas Lake. All statoblasts recovered appeared to be the same species, *Plumatella nitens*. *P. nitens* is a new species with a known range that includes all the Great Lakes states and extends east to Massachusetts (Wood, in press). *Plumatella* has been reported from Douglas Lake by several workers, including Smith & Green (1915), Brown (1933), Moffett (1943), Young (1945), and Eggleton (1952). The species was identified as *P. punctata* by Smith & Green (1915), and *P. repens* by Brown (1933). Dorsal and ventral statoblast valves of *P. nitens* are shown in Figure 2.

Concentrations ranged from 140 ml^{-1} to as few as three ml^{-1} of wet sediment in South Fishtail Bay (Figure 3). In the South Fishtail Bay and Fairy Island cores, statoblast concentration was greatest before European settlement and land clearance in this region (1880). Concentrations in the Grapevine Point core peaked at about the time of land clearing, but fewer samples were analyzed in this core. Concentrations were near 10 ml^{-1} in the lower sections of the core, increased to 20 ml^{-1} at 20 cm, then declined again. The deforestation horizon for this core was approximately 24 cm. The Grapevine Point core also had the lowest concentrations of the three cores, ranging from one to 20 ml^{-1}. This may in part reflect the distribution of *Plumatella* in the lake. Eggleton (1952) found only 20 colonies in a 3-year study of the central interdepression area (Figure 1), despite the fact that drifts of floatoblast

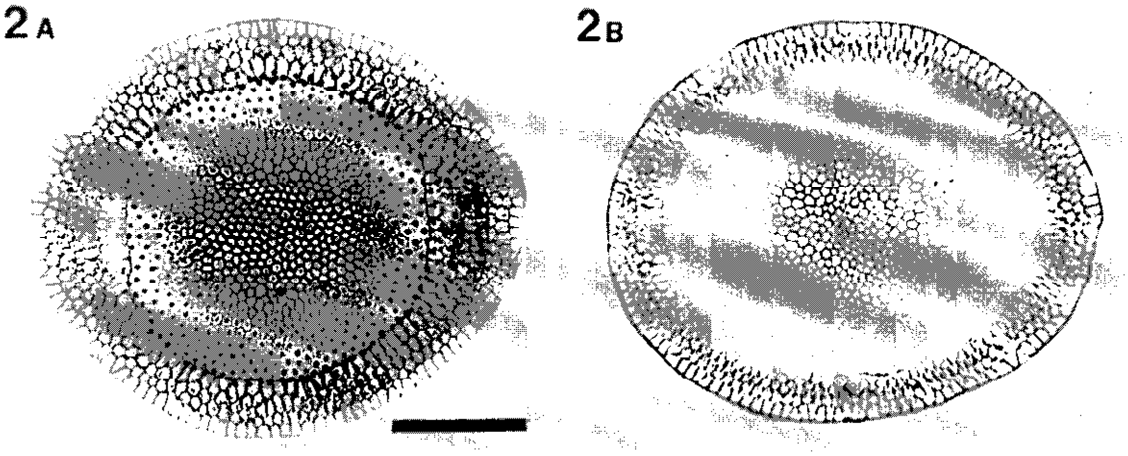

Figure 2. A. Dorsal valve of *Plumatella nitens* floatoblast recovered from Douglas Lake sediments. B. Ventral valve of *Plumatella nitens* floatoblast. There is a pollen grain underneath the lower edge of this valve. Scale bar = 0.1 mm.

valves were reported along the lake shore by Biological Station residents, indicating that *Plumatella* was possibly more abundant in other littoral areas of the lake. Brown (1933) reported *Plumatella* to be 'abundant' in Douglas Lake, but gives no quantitative data, and no indication of the distribution within the lake. Other workers reported it as 'present' or 'rare' (Smith & Green, 1915; Moffett, 1943; Young, 1945).

The most abrupt decline in statoblast abundance occurs in the South Fishtail Bay core (Figure 3). This occurs between 90 and 80 cm, which corresponds to the deforestation horizon. Statoblasts also decline in the Fairy Island core at the point corresponding to deforestation. If this were due to dilution by increased erosion following logging, one might expect some recovery at the top of the cores as sedimentation rate decreases, but this does not occur. In all three cores, the concentrations of statoblasts at the core base are greater than those at the surface.

At the deforestation, there is also an increase in the mass sedimentation rate, and the rate remains high above this horizon (Francis, 1995). Changes in concentration of statoblasts could result from dilution by this increasing sedimentation. Calculation of accumulation rates compensates for changes in sedimentation rates. Trends in statoblast accumulation rates are similar to trends in concentration for South Fishtail Bay and Fairy Island (Figure 4). Greatest accumulation rates occurred prior to settlement and deforestation. In the Grapevine Point core, however, statoblast accumulation increases from the deforestation level at 1880 to the core top. This may be a reflection of the increasing productivity in this basin that is suggested by other chemical and biological evidence such as increasing accumulation of organic matter and chlorophyll derivatives (Francis, 1995). Again, it should be noted that accumulation rates of statoblasts as well as the mass sedimentation rate are much lower in the Grapevine Point core than the other two cores. Reasons for the lower sedimentation rate in this basin are unclear but are possibly due to the smaller area of the watershed draining to this basin compared to the other two, and less littoral zone area in this basin.

If it is assumed that statoblast numbers in the sediments reflect population size of *Plumatella*, then it would appear that clear-cutting had a detrimental effect on this organism. The intensive logging and resultant erosion in the late 19th century may have affected *Plumatella* directly by interfering with the feeding of the animals, or indirectly, by reducing the macrophyte populations that *Plumatella* uses as substrate.

Experimental evidence that *Plumatella repens* does not survive well in high concentrations of suspended sediments is provided by Cooper (1988). The 96-h LC_{50} for *P. repens* was 160 mg l^{-1} suspended sediment. In concentrations above 200 mg l^{-1}, *P. repens* had 80 to 100% mortality rates. However, the water used in these toxicity tests had a high degree of colloidal clay particles. A high clay content would not be expected in runoff from the Douglas Lake catchment basin.

Crisman et al. (1986) found a correlation between the numbers of statoblasts accumulating in the surficial sediment of Florida lakes and the amount of macrophyte cover in the lakes. In lakes with <50% vegetated

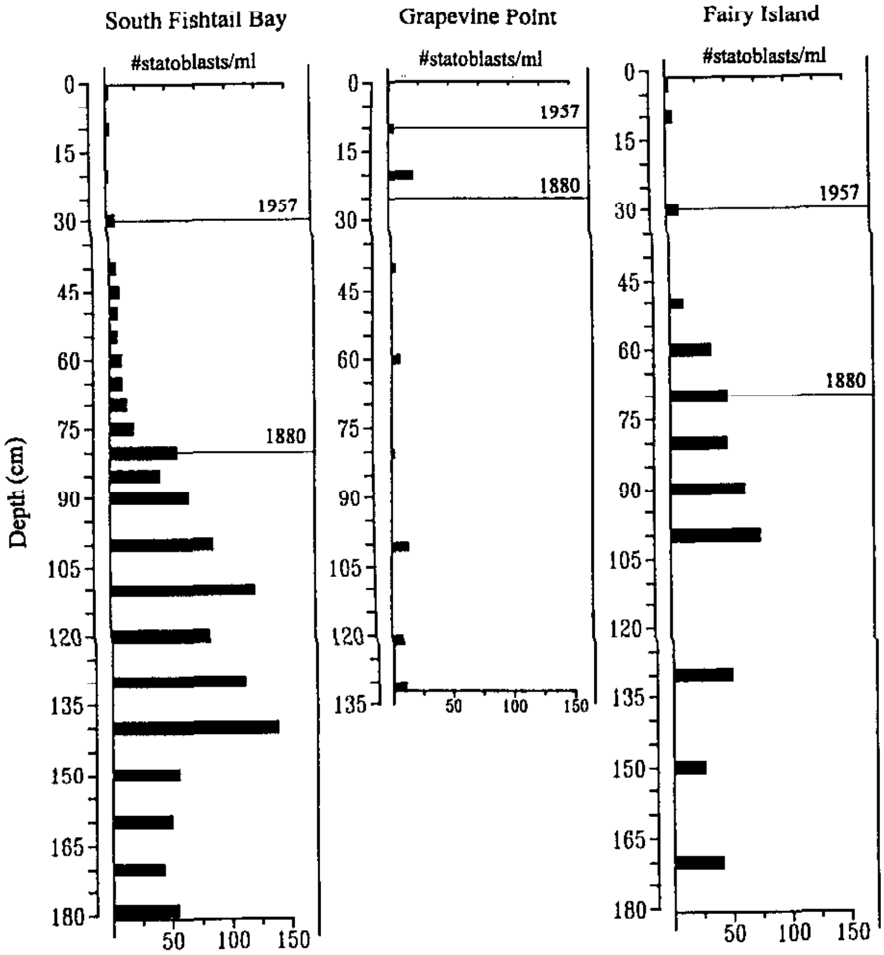

Figure 3. Concentration of *Plumatella nitens* statoblasts in three cores from Douglas Lake.

bottom, there was a positive correlation between statoblast numbers and plant coverage. In lakes with >50% plant cover, the relationship reversed, possibly due to less phytoplankton available for bryozoan food.

The decline in *Plumatella* abundance with clear-cutting in the watershed suggests that deforestation caused large changes in the littoral zone of Douglas Lake. The statoblast decline also corresponds to a decrease in accumulation rates of chironomid head capsules (Francis, 1995). The majority of these chironomids were littoral species, which also suggests major littoral zone changes. Although Stahl (1959) had incomplete data, he also found that *Plumatella* statoblasts numbers decreased at the same time as numbers of littoral chironomid head capsules decreased.

The increase in statoblast abundance apparent before settlement may reflect an early phase of eutrophication in the lake, or increasing development of littoral macrophytes as the lake filled in and size of the littoral zone increased. Diatom stratigraphies from South Fishtail Bay (Andresen, 1976; Stoermer, 1977) also suggest a trend of early 'natural' eutrophication before European settlement, and a more dramatic increase in productivity following deforestation. Another possible explanation for high statoblast abundance prior to settlement is that statoblast numbers in these cores reflect natural population cycles. It would be interesting to examine long cores from this lake to determine if such cycling exists, particularly since there has been little work on population dynamics of bryozoans. As Crisman et al. (1986) have suggested, paleolimnology may provide a long-term data set by which to study bryozoan population dynamics. A sediment core provides an integrated sample both spatially (bryozoans

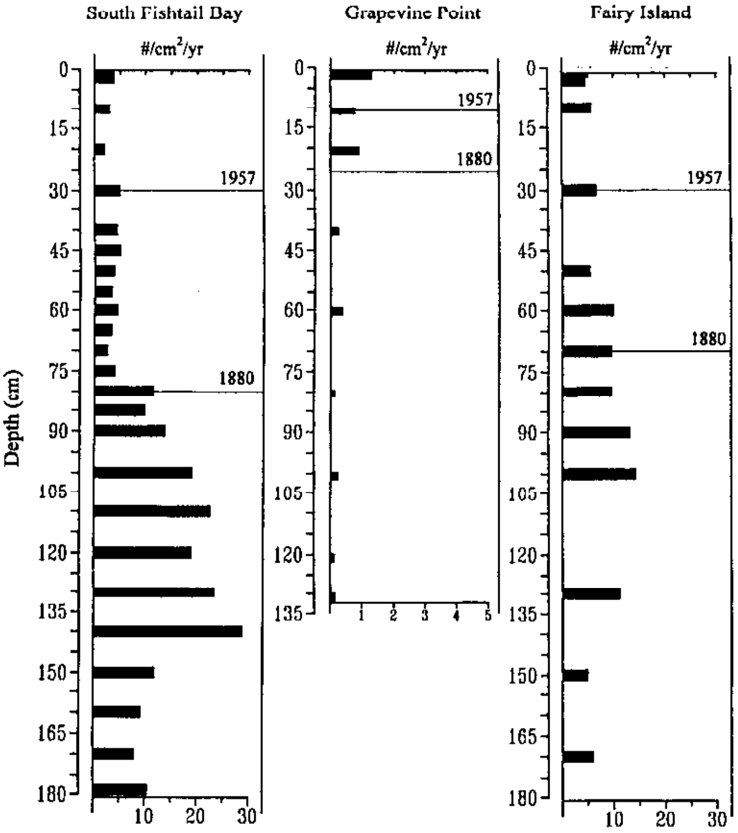

Figure 4. Accumulation rates of *Plumatella nitens* statoblasts in three sediment cores from Douglas Lake. Note difference in X-axis scale for the Grapevine Point core.

are often patchily distributed within a lake), and temporally, providing clues to population fluctuations over long periods of time.

Alternatively, the production of statoblasts may not be a reflection of the population size but rather of factors that influence statoblast production by individuals. There has been some investigation of factors influencing the viability and germination of statoblasts (Bushnell & Rao, 1974), but very little work on population dynamics and factors influencing production of statoblasts. It is known that *Plumatella* species are capable of producing many statoblasts at one time – up to 20 per zooid (Bushnell, 1974). The other bryozoan that is found in Douglas Lake, *Fredericella*, produces only one to two statoblasts per zooid (Bushnell, 1966). Bushnell (1966) indicates that *Plumatella repens* is much more susceptible to predation than is *Fredericella*, a possible reason for the high production of statoblasts by *P. repens*. Statoblasts can germinate during the same growing season in which they are produced and give rise to new colonies. It is possible that fluctuations in statoblast abundance in the sediments reflects some change in invertebrate predator populations.

The profiles of statoblast accumulation in these cores indicate that logging in the watershed had a profound effect on *Plumatella nitens*. Bryozoan statoblasts may be potential paleoindicators of siltation, macrophyte development, and lake productivity. Abundance of statoblasts has remained low throughout the recent sediments, suggesting some alteration to their habitat that has not returned to pre-disturbance conditions. Exactly what these conditions are that promote bryozoan growth and abundance is difficult to determine at this time. Interpretation of statoblast profiles would benefit from detailed studies of extant bryozoan ecology and population dynamics.

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