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Matching 30 years of ecosystem monitoring with a high resolution sediment record of chironomids and Cladocera from Lake Mývatn, Iceland

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The microfossil assemblages encountered in sediment cores are the result of two factors. One is the biota producing the organic remains that get incorporated in the sediments. The other factor is taphonomy, the process of transport and preservation of the remains. Unless there are serious taphonomic problems, it is usually taken for granted that changes in microfossil assemblages reflect changes in the biota. This assumption is rarely tested but it has been done both directly and indirectly. The indirect way is by demonstrating that the most recently sedimented microfossils in a lake correlate with the living biota of that lake. If this holds true over a wide array of different lakes one may infer that down-core changes in the microfossil assemblage of a lake reflect changes in its biota (Walker et al. 1984). The direct way to test the assumption is to search in sediment cores for fossil evidence of well-documented historical changes in the biota. This requires extensive monitoring of the biota and a high-resolution, well-dated sediment sequence. Only two studies known to us have used this direct approach, those of Leavitt et al. (1984) and Manca et al. (2007).

Leavitt et al. (1984), working in Tuesday Lake, Wisconsin, compared plankton monitoring data with annual to sub-annual palaeolimnological sediment records of
pigments and zooplankton to evaluate the outcome of three whole-lake manipulations. The relative abundance of Cladocera remains in seasonal sediment laminae was significantly correlated with the relative abundance of plankton species detected in the lake water from a corresponding time period. Manca et al. (2007) detected major changes in the trophic dynamics of Lago Maggiore in northern Italy by studying the community composition and body size of Cladocera in a high resolution sediment record covering a time interval from c. 1943 to 2002. This period coincided with long-term plankton studies in the lake. Variation in cladoceran body size derived from the sediment corresponded well with the monitoring data.

The ecosystem of Lake Myvatn in northern Iceland has been monitored since 1977, revealing extreme fluctuations in important food web components such as chironomids and cladocerans (Gardarsson et al. 2004, Einarsson and Örnólfsdóttir 2004, Einarsson et al. 2004). There is evidence that the fluctuations are driven by internal dynamics of the food web, most likely by a consumer effect of chironomid larvae on their food resources (Einarsson et al. 2002; Ives et al. 2008). The fluctuations have lead to the collapse of the local charr fishery (Gudbergsson 2004).

Both chironomids and Cladocera leave exoskeletal fragments in the sediment and have been used extensively as palaeolimnological indicators. In this study we compare the microfossil record of the most recently formed Lake Myvatn sediment with our monitoring data obtained through live trapping of chironomids and Cladocera.

**Methods**

Two sediment cores were used for the study. Both were retrieved at the same location in a sheltered bay, Breida, on the east side of Lake Mývatn. The aim of the first core was to search for well-known and easily identified tephra layers in the sediment in order to calculate sedimentation rate. The second core was 40 cm long and was analysed in 0.5 cm slices for cladoceran remains and chironomid egg capsules. Chironomid monitoring data is from a window trap that has been operated since 1977 at the Kalfaströnd farm, 1.2 km from the coring site (Gardarsson et al. 2004). The Cladocera monitoring is carried out
at five locations with activity traps, specially designed for epibenthic Cladocera (Örnólfsdóttir and Einarsson 2004). One central location was selected as representative of the main basin of Lake Myvatn, noting that long term fluctuations in the chydorid Cladocera appear to be synchronized over the whole lake (Einarsson and Örnólfsdóttir 2004). For the present study we used mean percent numbers calculated each year from the total catch of chydorid Cladocera in July and August.

**Results**

Two characteristic tephra layers were found in the first core, V-1477 and V-1717, dating respectively from the 15\textsuperscript{th} and 18\textsuperscript{th} centuries (the numbers refer to years C.E.) at 2.96 and 2.29 m depth in the sediment indicating a mean sedimentation rate of 2.79 mm/year between them. This gives a minimum sedimentation rate for the second core which includes the uncompacted organic top layer. The microfossil record revealed large fluctuations in chironomids and Cladocera. The years of high chironomid abundance, observed in the monitoring studies in 1979, 1987, 1992 and 2000 could be matched with the maxima of chironomid egg density in the sediment record (Fig. 1). Fluctuations of Cladocera, in particular *Alona rectangula*, *Alona quadrangularis* and *Alonella nana*, observed in the monitoring study are likewise correlated with the sediment records (Fig. 2). No simple depth-vs.-time function could be used to match the sediment and monitoring records. As expected, the sedimentary time scale is stretched due to increased water and organic content towards the top but the sedimentation rate also appears to have been variable on a smaller scale. This is not unexpected because of the high amplitude of the chironomid fluctuations. An amplitude of four orders of magnitude in the detritus-feeding chironomid larvae is likely to influence the sedimentation rate.

**Discussion**

The ecosystem fluctuations in Lake Myvatn create an opportunity to compare monitoring and sediment records. Matching of these records not only underpins palaeolimnology but also allows the ecosystem fluctuations to be tracked beyond the onset of monitoring, thus
adding enormously to our perspective of the lake’s food web dynamics and sensitivity to climatic change. The advantage can already be seen in that the Cladocera record has now been extended from 1990 back to 1978, showing one more cycle in the population of A. nana than previously known (Fig. 2).

Chironomid egg capsules have not been used in palaeolimnology before. They have the advantage of being abundant and of similar size and shape as cladoceran exuviae, allowing them to be counted along with the Cladocera fragments. The disadvantage is that they cannot yet be identified to species.

It appears possible to extend the high resolution record to the origin of the lake some 2300 years back. The high sedimentation rate means that the observed changes reflect real population trajectories. Even if the sediment record is smoothed by bioturbation, - the chironomid core data shows a fourfold difference between minima and maxima, while monitoring shows four orders of magnitude, (Fig. 1), - we can still observe changes in important parameters such as frequency and amplitude of fluctuations and how these have responded to anthropogenic impacts or long term climatic changes, e.g. the warming at the end of the Little Ice Age. After all, a period of 30 years of biomonitoring is hardly long enough to explore the dynamic behaviour of a lake foodweb.

A further advantage of the extension provided by the sediment record is that most of the microfossils derive from key components of the food web. The most abundant chironomid species seems to be the main driver of the ecosystem fluctuations (Ives et al. 2008), and the chironomids and Cladocera also feed the vertebrate populations, both fish and waterfowl. Much is already known about how these invertebrate fluctuations affect the population dynamics of the vertebrates (e.g. Gardarsson 2006).

References


Fig. 1. Concentration (upper panel, black line) and percent (lower panel) of chironomid egg capsules (percent of the total number of cladocerans+chironomids) in sediment core 2 from Breida, Myvatn. Grey line denotes the annual catch of chironomid flies from a local flytrap KS (time scale is stretched to visually match the core data. Numbers indicate years C.E. Note log-scale). The core data is smoothed as a three-point running average.
Fig. 2. Concentration (upper panel, black line) and percent (lower panel) of remains of *Alonella nana* in sediment core 2 from Breida, Myvatn. Grey line denotes the weighed mean percent catch of *A. nana* in monitoring studies (time scale is stretched, based on the chironomid data, as in Fig.1. Numbers indicate years C.E.). The core data is smoothed by a three-point running average.