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A modern snapshot of the isotopic composition of lacustrine biogenic carbonates: Records of seasonal water temperature variability

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Carbonate shells and encrustations from lacustrine organisms provide proxy records of past environmental and climatic changes. The oxygen isotopic composition ($\delta^{18}O$) of such carbonates depends on water temperature during carbonate precipitation, and on the $\delta^{18}O$ of the lake water. Lake water $\delta^{18}O$, in turn, is controlled by the $\delta^{18}O$ of precipitation in the catchment, water residence time and mixing, and by evaporation. A paleoclimate interpretation of carbonate $\delta^{18}O$ records requires a site-specific calibration based on an understanding of the local conditions.

For this study, carbonates and water were sampled in the littoral zone of lake Locknesjön, central Sweden (62.99°N, 14.85°E, 328 m a.s.l.) along a water depth gradient from 1 to 8 m. We took samples from living organisms and sub-recent samples in surface sediments of the calcifying algae *Chara hispida*, the mollusk *Pisidium*, and adult and juvenile instars of two ostracod species, *Candona candida* and *Candona neglecta*.

We show that neither the $\delta^{18}O$ of carbonates nor the $\delta^{18}O$ of water vary significantly with water depth, indicating a well-mixed epilimnion. The largest differences in the mean carbonate $\delta^{18}O$ between species are caused by vital offsets, i.e. the species-specific deviation from the $\delta^{18}O$ of inorganic carbonate which would have been precipitated in isotopic equilibrium with the water. After subtraction of these constant vital offsets, remaining differences in the mean carbonate $\delta^{18}O$ between species can mainly be attributed to seasonal water temperature changes. The lowest $\delta^{18}O$ values are observed in *Chara* encrustations, which form during the summer months when photosynthesis is most intense. Adult ostracods, which calcify their valves during the cold season, display the highest $\delta^{18}O$ values. This is because an increase in temperature leads to a decrease in fractionation between carbonate and water, and therefore to a decrease in carbonate $\delta^{18}O$. An increase in temperature also leads to an increase in the $\delta^{18}O$ of lake water through its effect on precipitation $\delta^{18}O$ and on evaporation, and consequently to an increase in carbonate $\delta^{18}O$, opposite to the temperature effect on fractionation. However, the seasonal and inter-annual variability in lake water $\delta^{18}O$ is small (0.5‰) due to the long water residence time. Seasonal

changes in the temperature-dependent fractionation are therefore the dominant cause of carbonate $\delta^{18}O$ differences between species.

Temperature reconstructions based on “paleo-temperature” equations for equilibrium carbonate precipitation using the mean $\delta^{18}O$ of each species and the mean $\delta^{18}O$ of lake water are well in agreement with the observed seasonal water temperature range. The high carbonate $\delta^{18}O$ variability of samples within a species, on the other hand, leads to a large scatter in the reconstructed temperatures based on individual samples. This implies that care must be taken to obtain a representative sample size for paleo-temperature reconstructions.