Supplementary Material 2

Using CharAnalysis for small hollow data

The macroscopic and microscopic charcoal records underwent statistical analysis using the program CharAnalysis, which is a set of diagnostic and analytical tools designed for analysing sediment-charcoal records when the goal is peak detection to reconstruct 'local' fire history (Higuera, 2009, CharAnalysis manual). CharAnalysis decomposed the record into low- and high-frequency components in order to determine significant fire episodes. First raw charcoal series was interpolated to equally spaced time intervals (using the age-depth model; Figure 2 in the article) in order to define the interpolated charcoal record C_{int} (particles cm^{-2} yr^{-1}). Brossier et al. (2014) have found that the median temporal resolution from the entire raw sequence (the default option in CharAnalysis) is too low for interpolation and therefore suggest that the optimal temporal resolution for the interpolation should be <0.12–0.20 times the mFFI (median fire free interval). For this purpose, we estimated the mFFI based on the fire scars observed in the three small hollows, resulting 5-year time steps for each hollow.

The non-log transformed C_{int} series was then smoothed with a Lowess smoother, robust to outliers, in order to define $C_{background}$ which is the low-frequency trend in C_{int}. We followed the guidelines of Brossier et al. (2014) and selected the smoothing window width to be the smallest width which resulted signal to noise index (SNI) >3 and the goodness of fit test values smaller than 0.1. This resulted us with the following smoothing window widths: Kämmekkä 800 yr, Naava 800 yr and Polttiais 1200 yr. We denote by C_{peak} the high-frequency component in C_{int} , obtained by subtracting $C_{background}$ from C_{int}. We used a local Gaussian mixture model for detecting possible fire-events from C_{peak} samples (Higuera, 2009, CharAnalysis manual). After this CharAnalysis performs a further "minimum count" screening where it removes those fire-events that appear to be insignificant. In the "minimum count" screening, CharAnalysis tests the fire-events one by one by assessing whether the interpolated charcoal accumulation rate (particles $cm^{-2}yr^{-1}$) in 75-year window before and after the event are from the same Poisson distribution. If an event passes the test, it is indicated as a significant fire-event.

If a group of possible fire-events occur in consecutive time points, CharAnalysis screens only the oldest event and if the test is passed, the significant fire-event is located in the oldest time point. Such a procedure works well when analyzing the lake charcoal sediment as their profiles are spiked with not many consecutive events. However, in the case of small hollows, we had many consecutive events and the oldest time point in the event group was not necessarily the one with the highest charcoal accumulation rate. Hence, we adjusted the significant event to be the one with the largest accumulation rate in the group or the middlemost one in the case when no single value was clearly higher than the others. Furthermore, a larger window than 75 years may be needed if the time window from the oldest event to the newest event in a consecutive fire-event group is longer than 75 years, but this was not the case here.

The macroscopic and microscopic charcoal abundancies along with the significant events are shown in Figure 1–3. The figures show that without the adjustment the event locations for the significant peaks would be occasionally remarkably different.

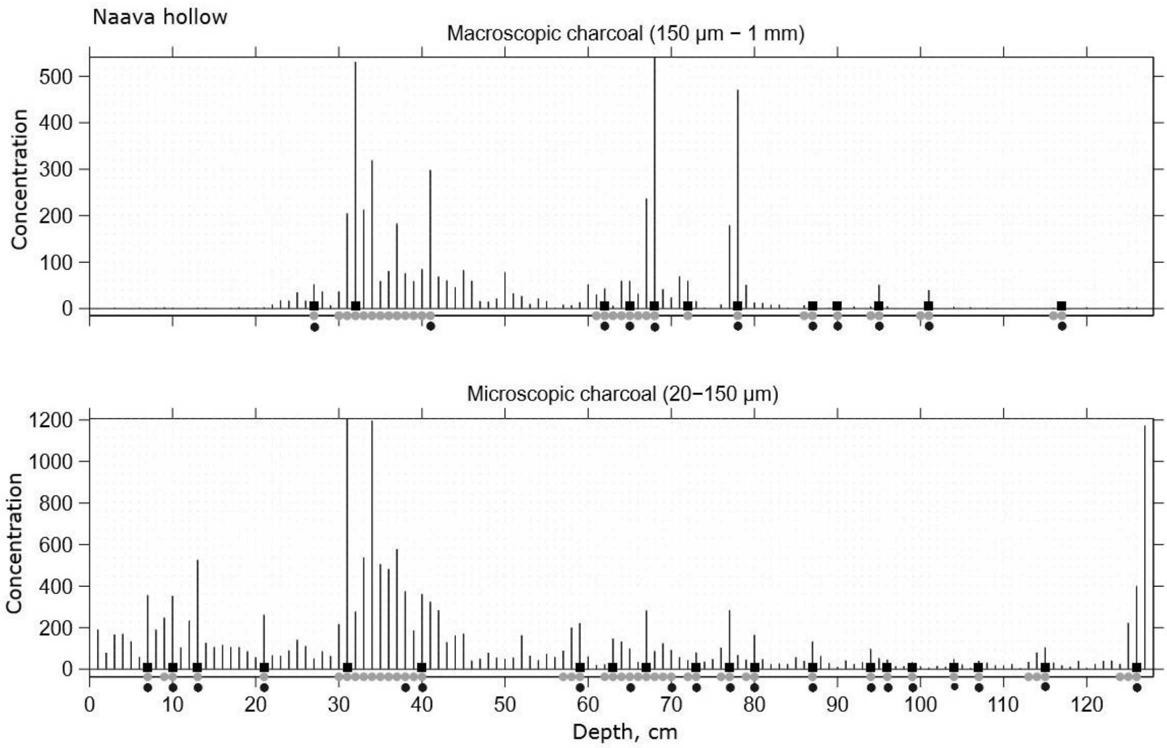

Figure 1. Macroscopic (upper panel) and microscopic (lower panel) charcoal abundancies for Naava hollow in the original sediment samples. Gray dots indicate the sample groups that are screened as significant. The black squares show the adjusted locations of detected events and black dots show the unadjusted locations of events (see text for further information). Note that the vertical axis has been cut from above for aiding the visualization.

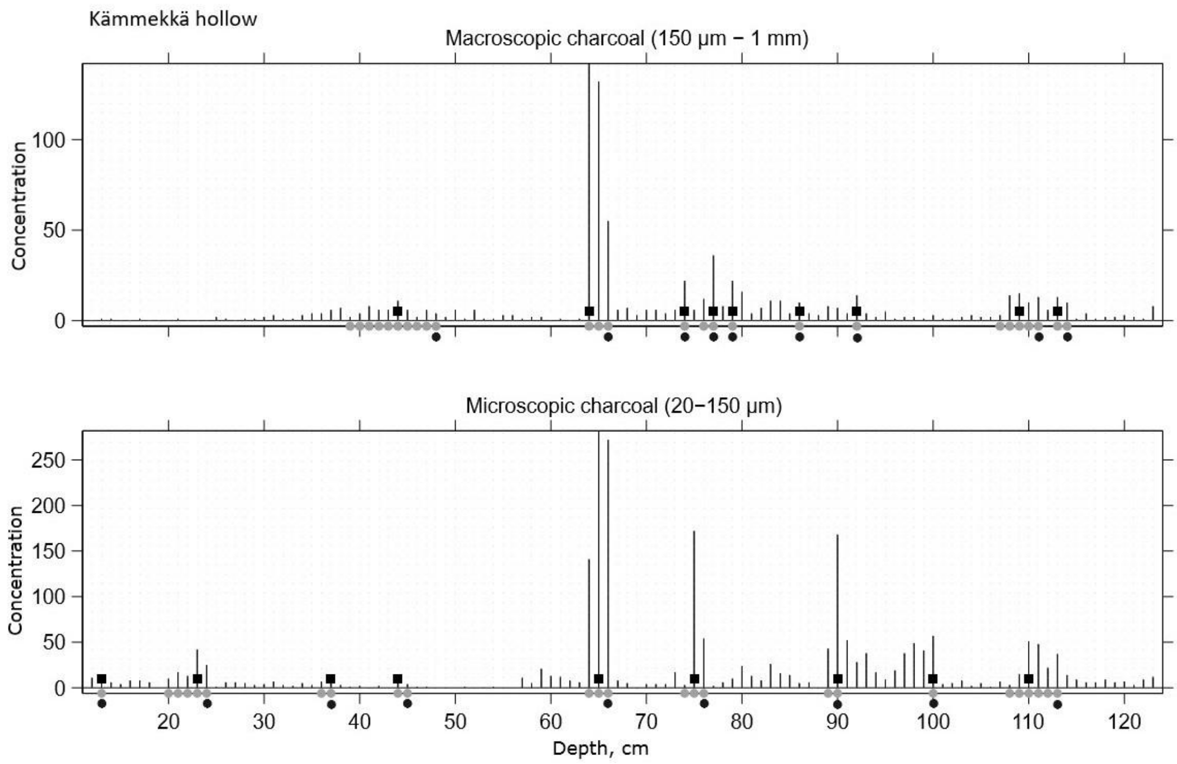

Figure 2. Macroscopic (upper panel) and microscopic (lower panel) charcoal abundancies for Kämmekkä hollow along with the identified events. See the caption of Figure 1 for further information.

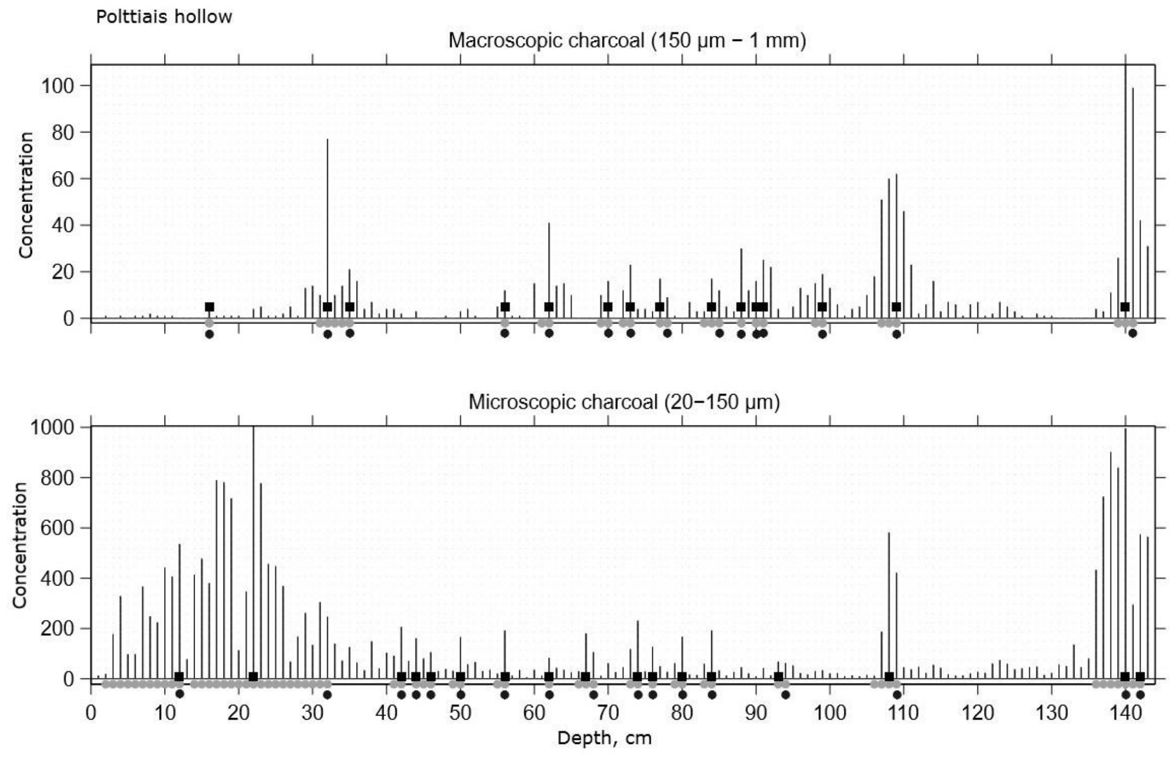

Figure 3. Macroscopic (upper panel) and microscopic (lower panel) charcoal abundancies for Polttiais hollow along with the identified events. See the caption of Figure 1 for further information.