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Supplementary Material

Using Fourier Transform Infrared spectroscopy to produce high-resolution centennial records of past high-intensity fires from organic-rich sediment deposits

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Radiocarbon Age-Depth Models

While 11 radiocarbon ages were determined for the CS-01 site (Table 2), some dates were excluded from the final age-depth model following outlier analysis. The MCMC simulation identified the 54–55 cm charcoal date as an outlier (posterior = 100), therefore, it was removed. The charcoal and seed dates at 23–24 cm depth created an inversion in the model, causing a discontinuity in the age sequence. Therefore, these two dates were also removed. Finally, the three dates in close proximity between 12–14 cm depth created larger uncertainties in the model due to variations in the $F^{14}C$ values. Therefore, the 12–13 cm seed age was removed for the final model (Supplementary Figure 2A).

Four radiocarbon dates were measured from the LS-02 site (Supplementary Table 1). Incorporating all four ages into the age-depth model caused a change in the date range of only nine years over 18 cm. This is most likely caused by the inversions in the ages between 2–3 cm and 23–24 cm. Therefore, the $F^{14}C$ values for the charcoal and seed at 2–3 cm depth were individually calibrated. The mean of the maximum probability range was determined for each date, and this year was input into the model as a calendar date. From this, the calendar year from the seed date at 2–3 cm was used to skew the model towards the older side of the bomb curve (Supplementary Figure 2B).

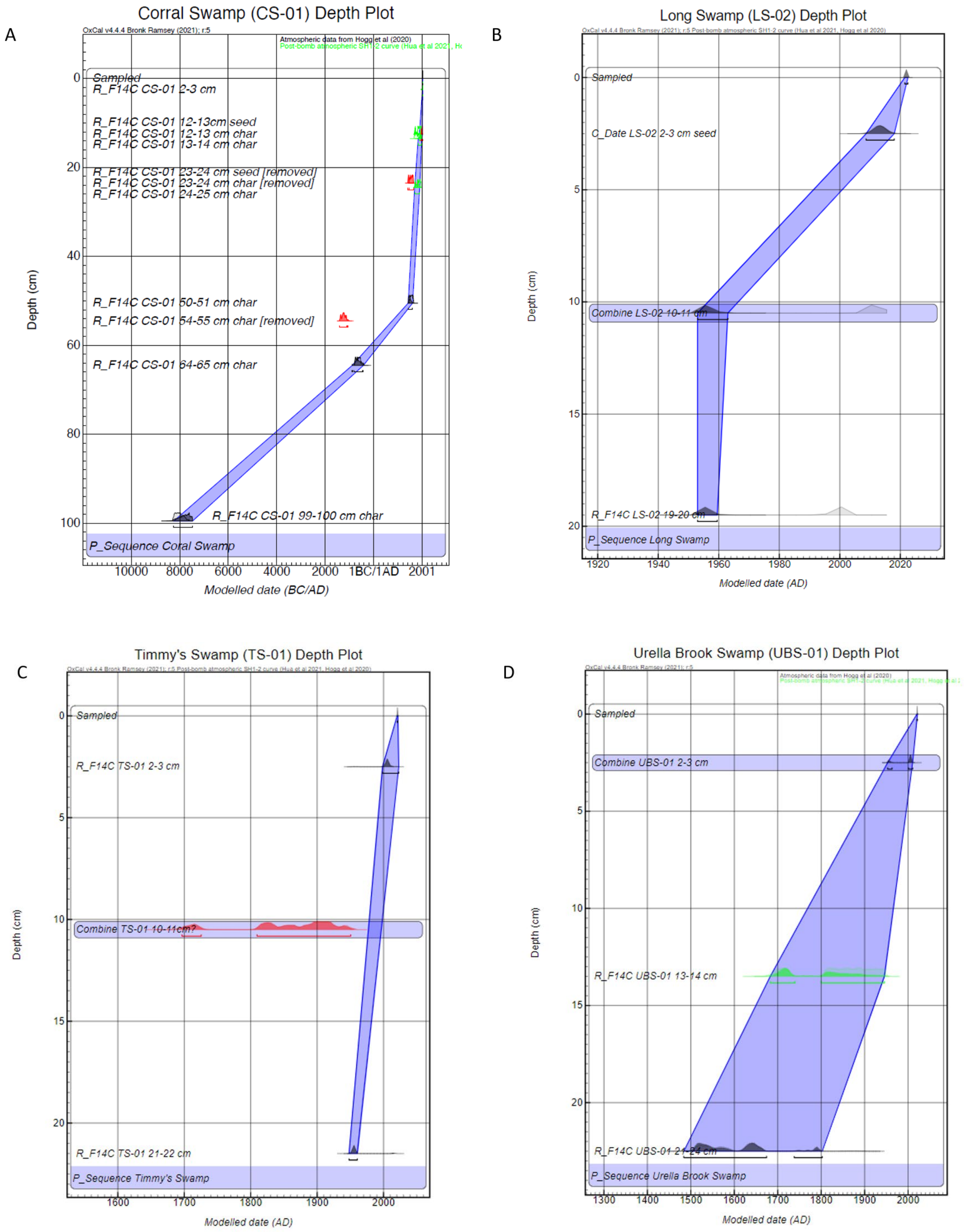
Three charcoal and one seed radiocarbon age was determined for the TS-01 site (Supplementary Table 1). Modelling all four dates with the "combine" function for the seed and charcoal date at 10–11 cm depth creates a straight line with minimal deposition between 10 and 22 cm. Removing either the 10–11 cm seed or the 10–11 cm charcoal date significantly increases the uncertainty of the ages for each depth. However, removing both ages at 10–11 cm creates a model constrained by the bomb peak (Supplementary Figure 3D), such that there is one age on either side of the bomb peak, therefore, this is the most suitable model for this site. Since both samples at 10–11 cm give similar ages, this suggests a possible inwash event that has deposited older sediments.

Like LS-02 and TS-01, four radiocarbon dates were measured for the UBS-01 site (Supplementary Table 1). Three total iterations were run for this age-depth model. The first used all dates with the "combine function" applied to the dates at 2–3 cm, the second removed only the 2–3 cm seed age, and the third removed only the 2–3 cm charcoal age. All three of these models yielded final models within approximately 20 years. Therefore, all dates were included, and the “combine” function was applied to the 2–3 cm dates in the final model (Supplementary Figure 2E).

Supplementary Table 1 Radiocarbon F^{14}C values and errors for the Corral Swamp (CS-01), Long Swamp (LS-02), Timmy's Swamp (TS-01) and Urella Brook Swamp (UBS-01). Asterisks denote ages removed from the final model.

Sample	F^{14}C Value	Error (1σ)	Lab Number
CS-01 2–3 cm charcoal	1.0497	0.0063	UNSW-1296
CS-01 12–13 cm charcoal	0.9834	0.0035	UNSW-1383
CS-01 12–13 cm seed *	1.1028	0.0045	UNSW-C-1384
CS-01 13–14 cm charcoal	0.9763	0.0041	UNSW-1297
CS-01 23–24 cm charcoal *	0.9364	0.0034	UNSW-1385
CS-01 23–24 cm seed *	0.9539	0.0034	UNSW-C-1386
CS-01 24–25 cm charcoal	0.9846	0.0041	UNSW-1298
CS-01 50–51 cm charcoal	0.9556	0.0040	UNSW-1299
CS-01 54–55 cm charcoal *	0.6845	0.0038	UNSW-1387
CS-01 64–65 cm charcoal	0.7300	0.0029	UNSW-1388
CS-01 99–100 cm charcoal	0.3290	0.0040	UNSW-1300
LS-02 2–3 cm charcoal *	1.1626	0.0065	UNSW-1301
LS-02 2–3 cm seed	1.0407	0.0047	UNSW-1302
LS-02 10–11 cm charcoal	1.0457	0.0045	UNSW-1303
LS-02 10–11 cm seed	0.9760	0.0067	UNSW-1304
LS-02 19–20 cm charcoal	1.0532	0.0044	UNSW-1305
TS-01 2–3 cm charcoal	1.0755	0.0044	UNSW-1289
TS-01 10–11 cm charcoal *	0.9821	0.0041	UNSW-1290

TS-01 10–11 cm seed *	0.9979	0.0076	UNSW-1290
TS-01 21–22 cm charcoal	1.0244	0.0059	UNSW-1292
UBS-01 2–3 cm charcoal	1.0846	0.0042	UNSW-1278
UBS-01 2–3 cm seed	1.0590	0.0046	UNSW-1279
UBS-01 13–14 cm charcoal	0.9826	0.0040	UNSW-1280
UBS-01 21–24 cm charcoal	0.9617	0.0041	UNSW-1281



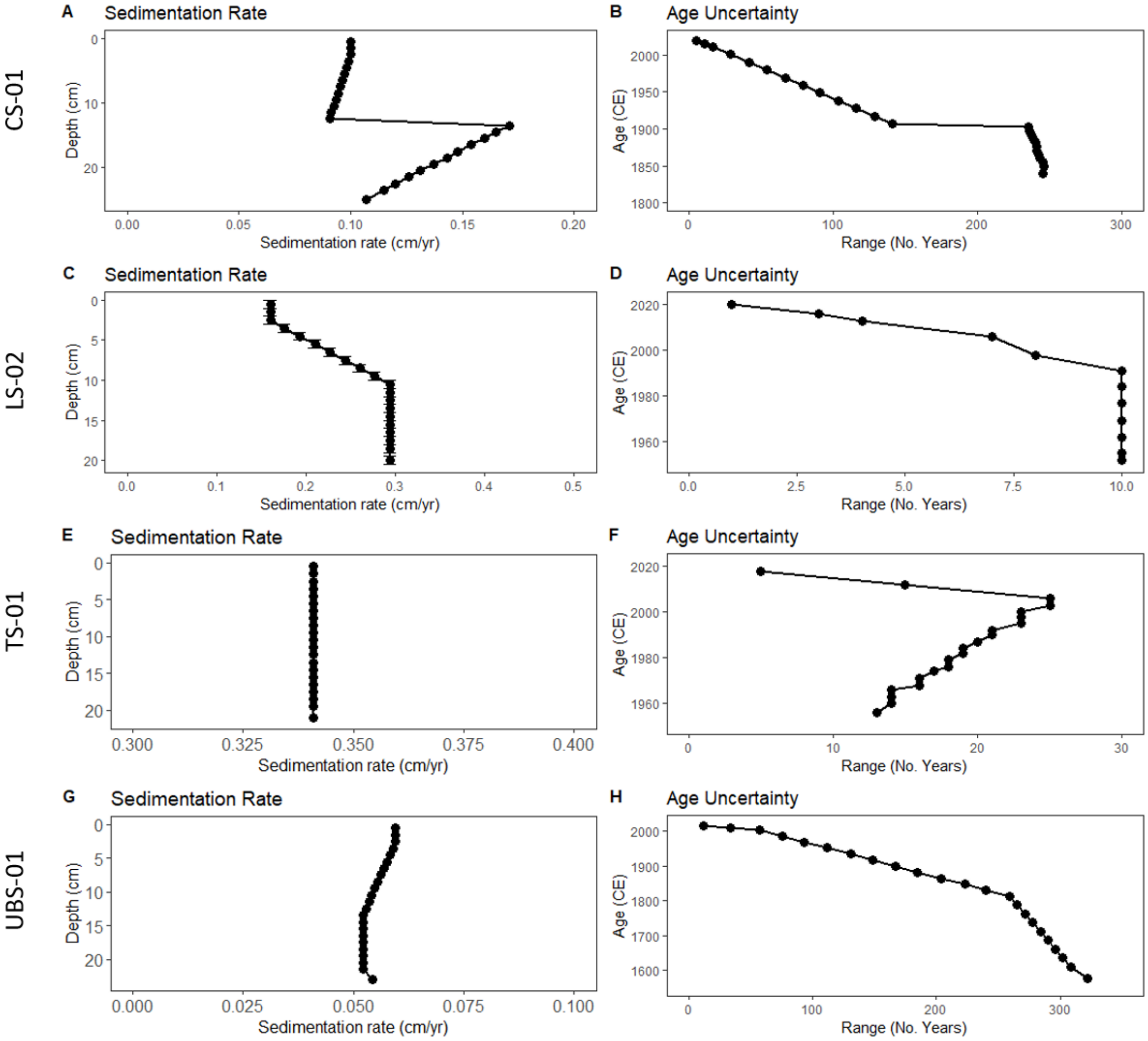
Supplementary Figure 1 Radiocarbon-based age-depth model plots for A) CS-01, B) LS-02, C) TS-01, and D) UBS-01. The blue area indicates the age uncertainty, and the red segments represent ages excluded from the model as outliers. Models were developed using OxCal 4.4 (Bronk Ramsey 2009).

Carbon and Nitrogen Abundance

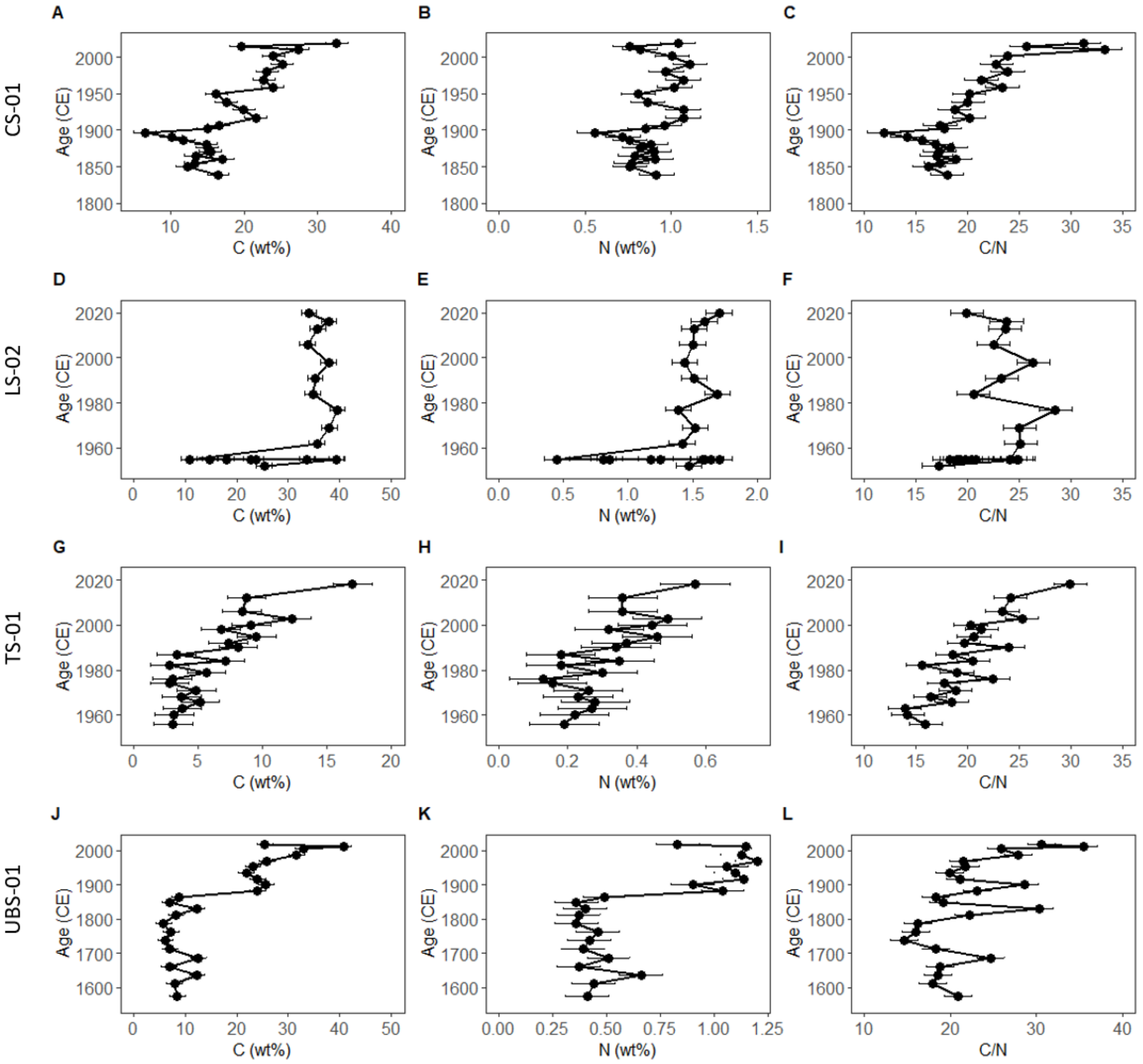
All four sites have comparable N content, typically around 0.5–2 wt%. Swamps are typically considered to be N–deficient, except when other nutrients become limited (Kuhry and Vitt 1996). Despite previous studies suggesting an increase in N content in fire-affected sediments due to increased erosion of soils, combusted leaf litter and ash enriched in nutrients, including N, post-fire (Thomas *et al.* 1999; Lane *et al.* 2008), there appears to be no significant increase in N content in layers hypothesised to record fires (Supplementary Figure 3B,E,H,K).. This may be due to the N content being low in these profiles, masking any significant changes following a fire.

Like the N content, C content is comparable across all sites, except for TS-01, where values are consistently lower (Supplementary Figure 3G). Whilst there is a small increase in C content for the uppermost fire layer in the CS-01 and UBS-01 sites, no significant correlation exists between C content and fire occurrence at the other sites (Supplementary Figure 3A,D,G,J). This agrees with the results found in Alexis et al. (2007) and Martín et al. (2012), who found a similar, limited response to fire events. Fire in nutrient-limited landscapes, such as the Blue Mountains, is believed to release nutrients (Raison *et al.* 1985; Orians and Milewski 2007). Therefore, it is surprising that there is no consistent change in C content with fire.

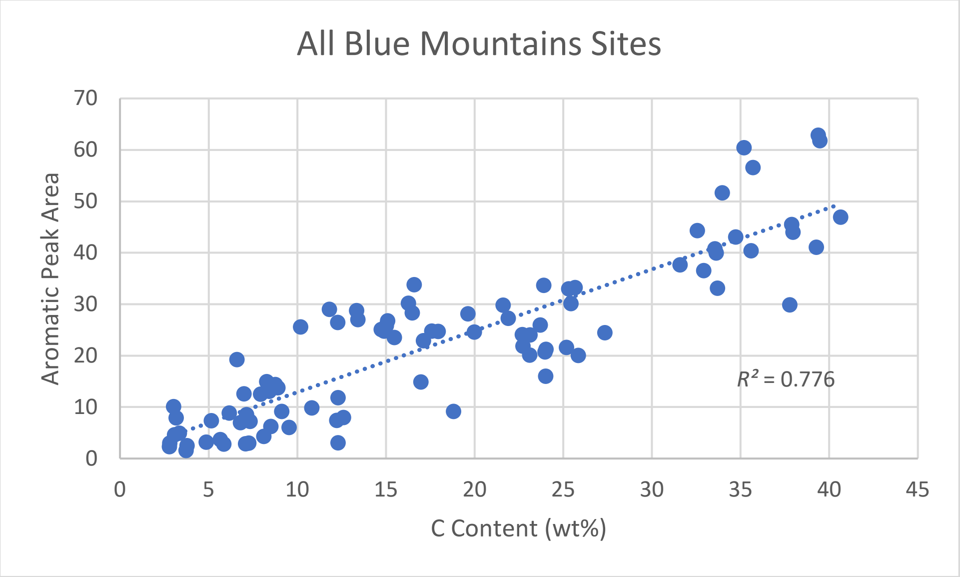
The C/N ratio typically decreases within increasing depth due to increased decomposition (Krull *et al.* 2004), however, many studies have shown a variable response to fire (e.g. Fernández et al., 1997; Martín et al., 2012; Santín et al., 2008; Sazawa et al., 2018). In some cases, a decrease in C/N ratio with increasing fire temperature has been observed (Santín *et al.* 2008; Abakumov *et al.* 2018; Sazawa *et al.* 2018), perhaps resulting from the loss of organic matter during combustion (Abakumov *et al.* 2018). Whilst the C/N ratio relies on the contents of both C and N, in peat swamps, variation in N content tends to be larger, and its influence on the ratio is more significant (Silva-Sánchez *et al.* 2016). Conversely, some studies have shown an increase in C/N ratio of fire layers (Krull *et al.* 2004; Mastrolonardo *et al.* 2015). Charcoal is highly resistant to decomposition and does not support microbial respiration, therefore, it has been suggested that fire-affected sediments should maintain a similar C/N ratio to the vegetation from which it is derived (Krull *et al.* 2004). In this study, there are no consistent trends with layers hypothesised to record known fire events and the C/N ratio for any of the four sites (Supplementary Figure 3C,F,I,L).



Supplementary Figure 2 The left column shows the sedimentation rate in cm/yr, and the right column shows the change in age uncertainty with depth in number of years. The first row displays data for CS-01, the second for LS-02, the third for TS-01 and the fourth for UBS-01.



Supplementary Figure 3 The left column shows the C content (wt%), the middle column shows the N content (wt%), and the right column shows C/N ratio (unitless) with relation to the radiocarbon-based age-depth model. The first row displays data for CS-01, the second for LS-02, the third for TS-01 the fourth for UBS-01.



Supplementary Figure 4 Cross-correlation between the C content (wt%) and the aromatic peak area of all four sites analysed, CS-01, LS-02, TS-01 and UBS-01. The strong positive correlation suggests that aromatic C is more dominant than mineral peaks in the band from 1750–1500 cm^{-1}.