Fire History of Lake Tanganyika (Mahale Coast) Watersheds Reconstructed from Macrocharcoal Records

Haixiang Mao[1], Andrew Cohen[2], Nur Sabrina Rosli[1], Michael McGlue[3], and Murtadha Malallah[4]

[1]University of Arizona
[2]Univ of Arizona
[3]University of Kentucky
[4]King Abdullah University of Science and Technology

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Abstract

Lake Tanganyika, located in central East Africa, is the longest and second deepest freshwater lake on Earth. Lake Tanganyika's diverse ecosystem and watershed are under threat today by human activities from extensive deforestation, climate change, and human-induced fires. Therefore, documenting fire and deforestation history in Lake Tanganyika's surrounding watersheds is crucial for improving watershed management around the lake in the future. Analyzing sediment charcoal records from sediment cores provides high-resolution paleolimnological evidence that reflects the timing and impacts of fire histories and landscape conversion. Macrocharcoal, an incompletely combusted residue that remains when plants materials were burnt by fire, can be transported away from the fire sites and deposited into the lake. We sampled and calculated macro-charcoal (>61 µm) sediment flux from three sediment cores, LT-98-20MR, LT-98-15M, and TANG14-1MC-1A from the lake's east-central coast. 20MR and 15M are 2.4 km apart, whereas 1A and 15M are 6.97 km apart. We have also compared our results with several previously studied cores from the central part of the lake. Core 15M, which is closest to the shore and has the highest sedimentation rates, showed peaks of charcoal flux from 1830 – 1850, 1896, 1910 – 1914 and 1996 AD based on correlation with a nearby core. Core 20MR, which is further offshore than 15M, has multiple sharp charcoal flux peaks at 1674, 1770, 1848 and 1881 AD, again using correlation with a nearby core. Core 1A, where the watershed has been intensively managed at Kalilani Bay in recent decades (McGlue et al., 2021), shows two significant peaks at 1668 and 1808 AD. The difference in timing of the distributions of sediment charcoal flux peaks from our study indicates these charcoal histories record localized wildfires. Some of these may correlate with the late Little Ice Age dry period in the late 18th – mid 19th C, whereas other more recent ones maybe linked to human activities such as land clearance for cassava cultivation. Low fire frequencies at most sites during the late 19th – mid 20th C may correspond to reduced human populations and disease outbreaks during that period.

Fire History of Lake Tanganyika (Mahale Coast) Watersheds Reconstructed from Macro-Charcoal Records

Haixiang Mao [1] (maohaixiang625@email.arizona.edu), Andrew S. Cohen [1], Nur Sabrina Rosli [1], Michael McGlue [2], Murtadha Al Malallah [3]

[1]Department of Geosciences, University of Arizona; [2]Department of Earth and Environmental Science, University of Kentucky; [3]King Abdullah University of Science and Technology

Introduction

- High frequencies of human-caused fires can threaten the environment and ecosystem, resulting in high levels of greenhouse gas release, altering landscape hydrology and air quality and damaging habitats (Shlisky et al., 2009).
- Lake Tanganyika, located in central east Africa, is the longest and second deepest freshwater lake on Earth. Lake Tanganyika's diverse ecosystem is under threat today by human activities from extensive deforestation, climate change, and human-induced fire. Therefore, documenting fire and deforestation history in Lake Tanganyika's surrounding watersheds is crucial for improving lake management in the future.
- Slash and burn deforestation supporting land conversion for agriculture by lakeshore inhabitants often leads to soil erosion, which is intensive around the northern Mahale coast watersheds of the central coast of Lake Tanganyika, especially since the 20th Century.
- As the byproduct of fires, macrocharcoal (in this study, sieve size was > 61 μm) are direct indicators of biomass burning, in which the large particle sizes usually imply transport by fluvial and nearby aeolian transport into lakes during a short period of time (Graves et al., 2019). Paleolimnological records of charcoal can provide high-resolution archives that reflect both local wildfire histories, landscape conversion, and climate changes.
- Cores LT-98-20MR, LT-98-15M, LT-98-21MR, and TANG14-1MC-1A were collected in Lake Tanganyika, Eastern Africa. Cores 20MR, 15M, 21MR, and 1A were processed in the current study and compared with lake level, and lake temperature, whereas cores 25M, 18M, KH1, 2A, and 6A were analyzed in a prior study.

Methods

- Sampling: LT-98-20MR is a 55 cm multicore, LT-98-15M is a 52 cm multicore, LT-98-21MR is a 40 cm multicore, and TANG14-1MC-1A is a 31 cm multicore. Wet samples of 5-10 gm were processed for every cm of core.
- Wet samples were weighted and then screen washed (61-micron sieve). A separate wet aliquot was weighed and dried at 60°C to determine water content.
- Charcoal was counted using a Leica M165 C stereo microscope (1 to 2.5 mm scale bar). Six Macro-charcoal fragments from core 15M, 20MR, and 21MR (4-8mm) were picked for ^{14}C analysis.
- The age model for the 21MR core was based on ^{14}C, whereas age models for 20MR and 15M were based on assumption of similar sedimentation rates to the nearby Nkonkwa (TANG17-11A-1U) and Kalilani (TANG14-1MC-1A) cores (McGlue et al., 2021) and LT-98-18M (McKee et al., 2005).

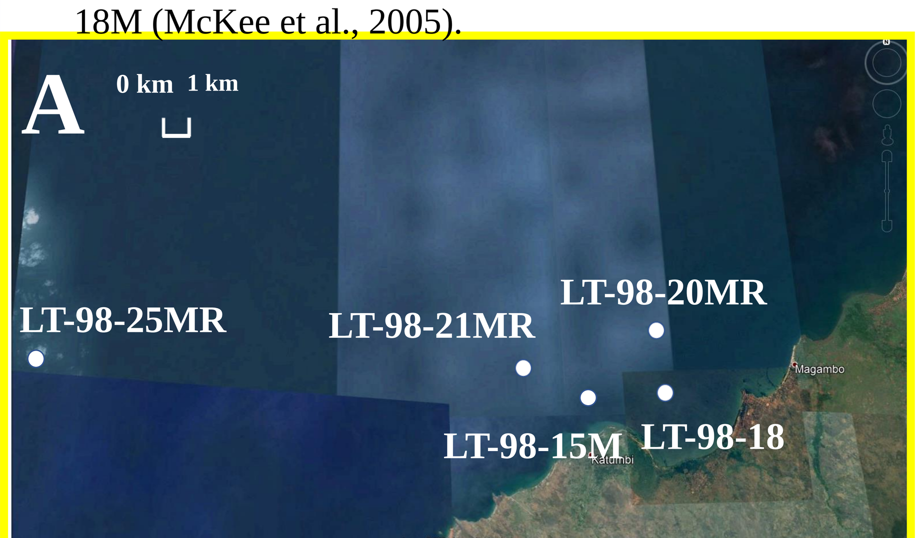
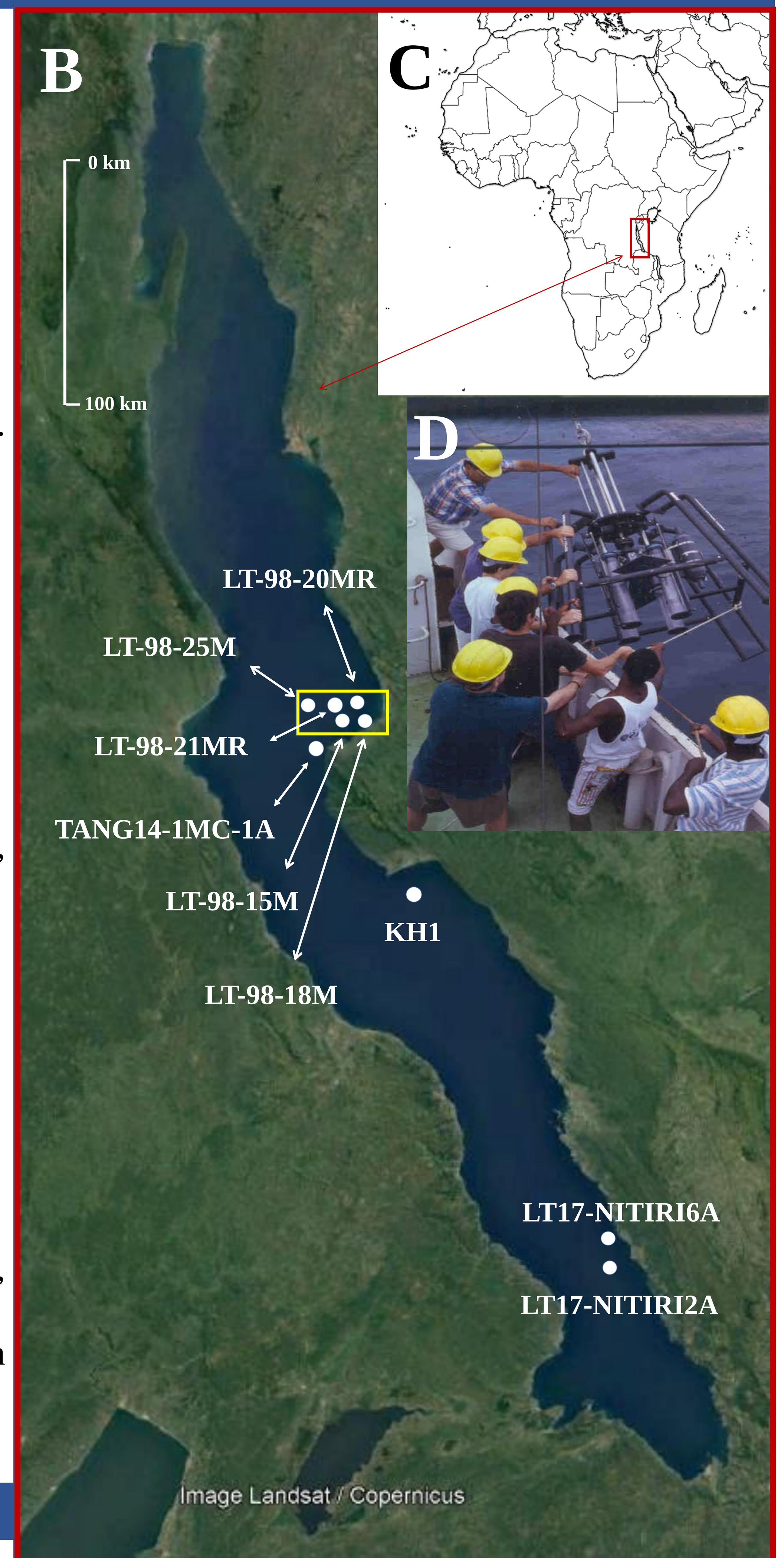


Figure A. Locations of cores enclosed in the yellow box in **B**. **Figure B.** Lake Tanganyika map. **Figure C.** Africa map. **Figure D.** Lake Tanganyika multi-coring.

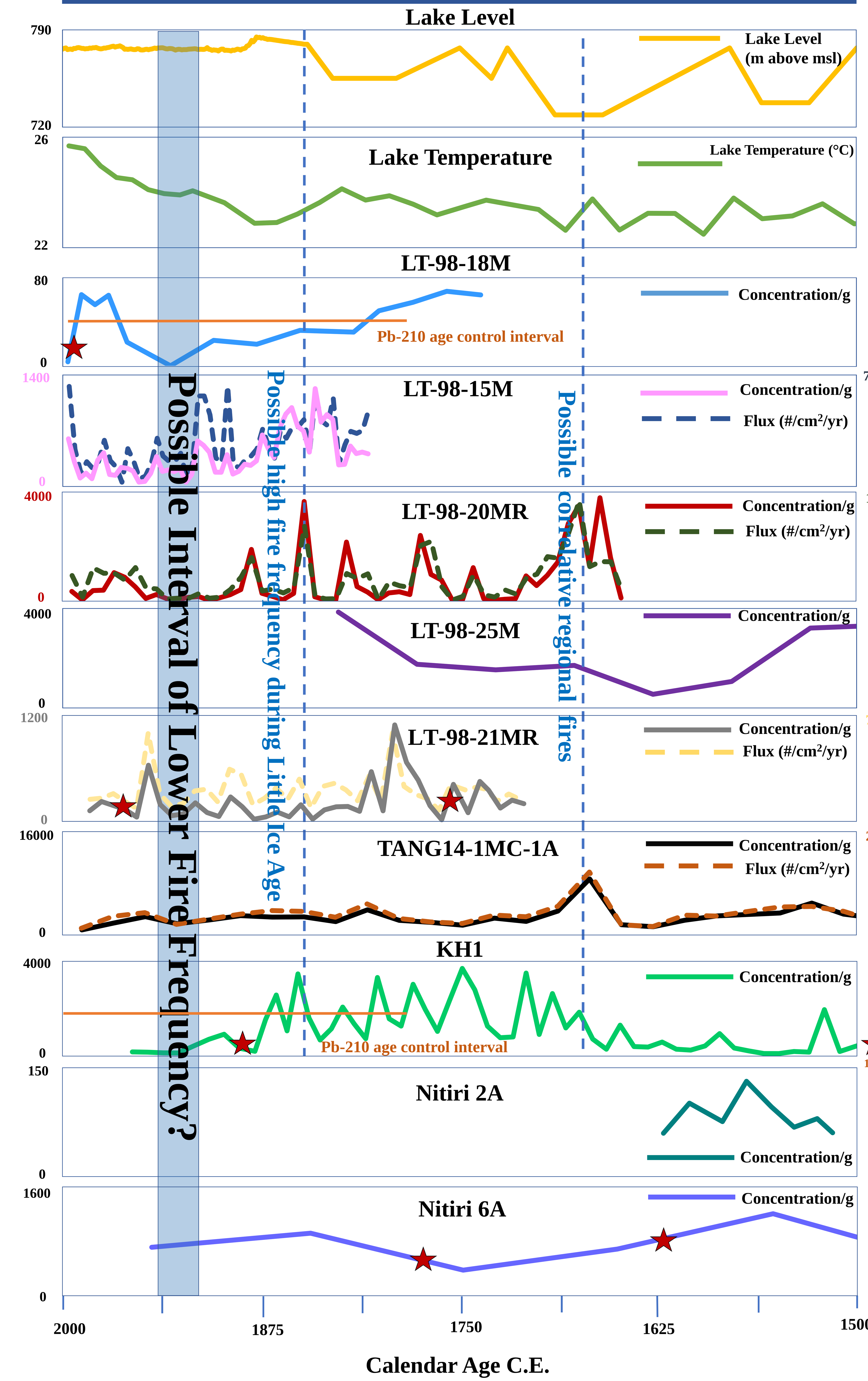
Core Locations



Macro-Charcoal Images

Figure E. Macro-charcoal particles at 48-49cm depth (15M) with **1mm** scale bar.
Figure F. Macro-charcoal particles at 30-31cm depth (23M) with **2.5mm** scale bar.
Figure G. Macro-charcoal particles at 7-8cm depth (21M) with **2.5mm** scale bar.
Figure H. Macro-charcoal particles at 20-21cm depth (23M) with **2.5mm** scale bar.

Results



- **Charcoal/fire histories from Lake Tanganyika cores compared with lake level and paleotemperature records:** Charcoal concentration (#/gm) & charcoal flux (#/cm²/yr) versus calendar age (C.E.) on multiple sediment cores collected in Lake Tanganyika and lake temperature (°C) (Tierney et al., 2010) and lake level (m) (Cohen et al., 1997) and Alin et al., 2003)). The red asterisks indicate ^{14}C dates (core 18M: 1994, KH1: 1896 & 1478, 6A: 1785 & 1620 C.E.) and the orange horizontal lines indicate Pb-210 age control intervals (core KH1: 1795-2005, 18M: 1767-1998). The blue shaded area indicates possible interval of lower fire frequency, the blue dash lines indicate possible correlative high fire events during Little Ice Age dry period and the late 17th century regional fires. C.E. = Common Era. Dash lines on core 15M, 20MR, 21MR, and 1A indicate charcoal flux. The vertical scales of charcoal flux are on the right side.

Discussion & Conclusion

- In general, there are no obvious relationships between charcoal abundances and lake levels or lake temperature changes.
- **Core 18M** has the charcoal concentration peaks in 1740 -1800 C.E. and the late 20th Century.
- **Core 15M**, which is closest to the shore and has the highest sedimentation rates, showed peaks of charcoal flux in 1830 – 1850, 1896, 1910 – 1914, and 1996 C.E. at the top of the core.
- **Core 20MR** has significant charcoal flux peaks in approximately 1674, 1770, 1848, and possibly 1881 C.E.
- **Core 25M** has charcoal concentration peaks in approximately 1530 and 1786 C.E. Charcoal concentration decreases from 1530 to the lowest level in 1635, then increases to the highest level in 1844 C.E.
- **Core 21MR** shows significant charcoal flux and concentration peaks in approximately 1790 and 1946 C.E.
- **Core 1A** has two notable charcoal flux peaks in approximately 1668 and 1808 C.E.
- **Core KH1** has multiple charcoal concentration peaks in 1682 – 1712, 1740 C.E., a broad peak is from 1760 to 1850 with peaking in 1792, and 1832-1852 C.E. Since **core KH1** is further offshore than the other cores, the charcoal concentration peaks indicate less impact by smaller local fires.
- **Core 2A** shows the highest charcoal concentration peak in approximately 1569 and a relatively lower peak in 1605 C.E.
- **Core 6A** has charcoal concentration peak in approximately 1528 C.E. Concentration decreases from approximately 1553 to 1748, then increases to 1844 C.E.
- **The difference in timing of the distributions of sediment charcoal flux and concentration peaks from our study indicates these charcoal histories record localized wildfires. Generally, charcoal concentration and charcoal flux peaks are consistent with Little Ice Age aridity in the late 18th to mid 19th Century. The peaks at 1670 - 1680 may be indicative of a more regional fire. Other more recent common features between cores may be related to human activities such as land clearance for cassava cultivation. Low fire frequencies at most sites during the late 19th – mid 20th C may correspond to reduced human populations and disease outbreaks during that period of time.**

References & Acknowledgements

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