Underwater Dendrochronology of Sierra Nevada Lakes

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Abstract

Submerged, apparently rooted trees found in Lake Tahoe, Fallen Leaf Lake, and other Sierra Nevada lakes indicate the possibility of large-magnitude, rapidly-occurring but long lasting droughts in lake level. These changes have usually been attributed to extended periods of very dry conditions during the mid and late Holocene, with the most recent mega-droughts happening during Medieval times. Given the relevance of this hypothesis for sustainable water management in the Lake Tahoe Basin and surrounding areas, it is then necessary to answer the question “Are submerged trees indicators of past mega-droughts, or were they transported into the lakes by past slope movements caused by geomorphic or seismic events?” Tree-ring samples collected from the submerged trees, and crossdated against existing and newly developed long chronologies, can provide a clear map of the historic periods when trees now underwater were alive. In 2005, three wood samples were retrieved from submerged trees in Fallen Leaf Lake. For dendrochronological dating, we developed a western juniper (Juniperus occidentalis) reference chronology that spans the period from AD 543 to 2003. One underwater sample, i.e. a branch cross section cut from a standing tree, was crossdated with the master chronology for the period AD 1085-1153. This initial result shows that, while it is feasible to date underwater trees, many more wood samples are needed to distinguish between climatic vs. non-climatic origin (and significance) of submerged trees in the Sierra Nevada.

Underwater Wood Samples from Fallen Leaf Lake

The identification of underwater stumps and trees was carried out using an ROV (remotely operated vehicle) that can hold a high resolution color video and retrieve small surface samples using a gripper down to a depth of about 150 m (see picture on the right). This ROV was developed by one of us (J.A. Kleppe), and has been extensively tested in Fallen Leaf Lake, where a total of 13 submerged trees have been located. Some of these trees are over 30 m tall with a circumference > 4 m (Kleppe 2005).

For tree-ring dating, samples were collected by cutting branches from trees standing underwater (see picture below). Two samples contained enough rings (>50) to allow the possibility of dendrochronological dating: these branch cross-sections are shown below, together with their location in the lake.

The 3 wood samples have anatomical features of pine species, and show decomposition on the outside.

The section contains a sequence of about 200 rings.

Fallen Leaf Lake (see map on the left) has a surface area of 5.2 km², is relatively shallow and narrow (it fills a glacial valley), and drains into Lake Tahoe. Its watershed covers an area of approximately 42 km². Submerged trees being studied are at a depth of about 36 m below the lake surface.

The ratio of watershed to lake surface area for Fallen Leaf Lake is (42:5) or 8.4. This indicates that the lake surface level is more closely tied to the water level in the lake, and that the lake surface level is more closely tied to the water level in the lake.

Additional tree-ring samples were obtained by raising a log from the bottom of the lake using a a large floating crane (see pictures below). A section cut from the log at a height of about 5.2 m above root level was used for tree-ring dating. The number of rings on this section varied from 130 to 220.

Tree-Ring Dating

For dating purposes, the only local species that could yield a chronology longer than 1000 years was western juniper (Juniperus occidentalis). Samples that displayed “ring wedging” (groups of rings not uniformly present around the stem; see picture below) were excluded. The master chronology was formed by a total of 22 series from 16 different trees, and spanned the period AD 543-2003, or 1461 years, with sample depth ≥ 3 series from AD 654.

Overall series intercorrelation for the chronology is 0.532, with a mean series length of 393 years. The longest continuous segment in the chronology is from a log that covers 888 years, from AD 543 to AD 1410. The longest core from a living tree included 682 years, from AD 1322 to 2003. Out of 8466 rings used to build the chronology, only 3 are locally missing, indicating a high level of continuity in the growth patterns (see picture on the right).

From a correlation map with all other tree-ring chronologies available for the western USA (see below), it is clear that the western juniper master chronology is closely related to other Sierra Nevada sites.

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This section contains a sequence of about 70 rings.

As more and more tree-ring samples are collected, dated, and entered into a master chronology, they will also provide a way to construct a continuous, annually resolved record over several millennia. By synthesizing these results and combining data from other sites, a more comprehensive picture of past climatic conditions can be painted. This information will be crucial for understanding the impacts of climate change on the Sierra Nevada, and for developing strategies to mitigate its effects. This study was funded by the National Science Foundation (NSF) under Grant ATM-CAREER-0132631.