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Developing new sources of proxy climate data from historical structures in the Lake Michigan-Huron Basin

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ABSTRACT

The need to understand lake level variability in the Great Lakes is underscored by record low stands in 2012 followed by a quick shift back to the historic averages by 2014 in the Michigan-Huron basins. These rapid changes have important implications for near-shore ecology, sedimentology, water management, tourism, and industrial commerce throughout the Great Lakes region. Attempts to reconstruct climatic controls of lake level variability from tree rings have either been based on spatially and temporally limited tree-ring data sets or tree-ring records from sites in the Pacific Northwest teleconnected to Great Lakes climate. The necessary local tree-ring chronologies to develop more robust reconstructions of climate and its relation to Great Lakes levels simply do not exist. A particularly evident gap in available data exists in Lower Michigan, where logging in the 1800s removed most old growth forests. Here we report the development of three new tree-ring chronologies derived from a pier near the mouth of the Kalamazoo River that was constructed *ca.* 1871. The new chronologies include multi-century *Pinus resinosa* (1673–1878), *Quercus* spp. (1628–1847), and *Tsuga canadensis* (1643–1864) tree-ring data that exhibit patterns of correlation among reference chronologies of the same species indicative of origins within the Great Lakes Region, and possibly Lower Michigan. Our results illustrate the excellent potential to develop a more complete network of sites with tree-ring data throughout the Michigan-Huron Basin by utilizing wood incorporated into historical structures.

Introduction

Water resources in the Great Lakes region of North America will experience unprecedented pressure in the next century due to factors that include human population growth and increasing water demand, invasive species and their associated impacts, channel modification and dredging, and climate change (Beeton, 2002; Lofgren et al., 2002). A precursor to the dramatic ecological and economic impacts of these pressures was evident in 2012 as Lake Michigan lake levels dropped to record lows (U.S. Army Corps of Engineers, 2013). To better understand the mechanisms driving these changes and prepare for the future we must set current conditions in the context of the past (Swetnam et al., 1999).

Instrumental records of Lake Michigan water levels maintained by the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Army Corp of Engineers span 1860 to the present day, while a longer Lake Michigan-Huron paleohydrograph based on sedimentologic studies of paleoshorelines provides estimates of lake levels over the past *ca.* 4500 years (Argyilan et al., 2010; Baedke and Thompson, 2000; Thompson and Baedke, 1995, 1997). The baseline determined by instrumental data does not provide a sufficient temporal perspective to understand the long-term dynamics of lake-level variability while the currently-available paleohydrograph lacks sufficient temporal resolution to examine the role of inter-annual climate variability in driving past lake-level changes, particularly with respect to extreme high and low stands (Quinn and Sellinger, 1990).

Tree rings have been used extensively as proxies for past hydrologic conditions around the world and may offer insight into the influence of climate variability on lake levels over recent centuries, yet only a few lake level and net basin supply reconstructions for the Great Lakes have been attempted, including those for Lake Superior (Brinkmann, 1992), Lake Michigan-Huron (Quinn and Sellinger, 2006), Lake Erie (Wiles et al., 2009), and the Great Lakes as a whole (Brinkmann, 1987). These reconstructions identified important variability and trends that are not captured by instrumental records, yet substantial room exists to improve the available tree-ring data on which these are based. In particular, existing reconstructions have been limited by the low number and early end dates of tree-ring chronologies available for the region. Quinn and Sellinger (2006) used tree-ring data from six sites around Lake Michigan, the end dates of which limited their calibration between tree growth and lake level to the period 1900–1961. Brinkmann (1987, 1992) used 16 local tree-ring chronologies calibrated over the period 1900–1964 to reconstruct net basin

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supplies for the entire 765,000 km^2 Great Lakes Basin, while Wiles et al. (2009) used no local chronologies to reconstruct Lake Erie levels and instead relied on climatic teleconnections between the Gulf of Alaska and the Great Lakes region.

Updating existing tree-ring chronologies and developing new chronologies at additional sites will provide a more complete network of data points capable of capturing regional variations in climate that influence lake levels (Brinkmann, 1992; Quinn and Sellinger, 2006). Efforts are ongoing to update existing tree-ring chronologies (Larson et al., 2013), but opportunities to develop new tree-ring chronologies across much of the region are limited due to the nearly pervasive historical logging and widespread disturbance associated with European settlement and land use change (Dickmann, 2009). This is particularly true in the lower peninsula of Michigan where logging of pre-settlement forests was nearly complete by the early 1900s (Whitney, 1987). In the absence of living old-growth trees, wood from primary forests incorporated into historical structures can provide a source of tree-ring data that extends over multiple centuries (Schweingruber, 1996).

Here, we report the development of long-term tree-ring records from historical structures within the Lake Michigan-Huron Basin in an area of Michigan where no such records currently exist (Fig. 1). We then examine the characteristics of these series to determine their geographic origin and the potential of establishing a network of multi-century tree-ring records across the basin to improve the available data and estimations of past lake level and its climatic drivers.

Methods

Our study focused on the remnants of a pier constructed at the mouth of the Kalamazoo River *ca.* 1870, near the town of Saugatuck, Michigan (Fig. 2a and b). The pier was originally constructed to narrow the river channel, increase flow rates, and reduce the need for dredging to maintain the channel for shipping (Fig. 2c). A new channel to Lake Michigan was excavated upstream in 1903 that resulted in the eventual infilling of the original channel and the formation of an oxbow lake (Adams, 1905). At the time of our sampling, the only evidence of the

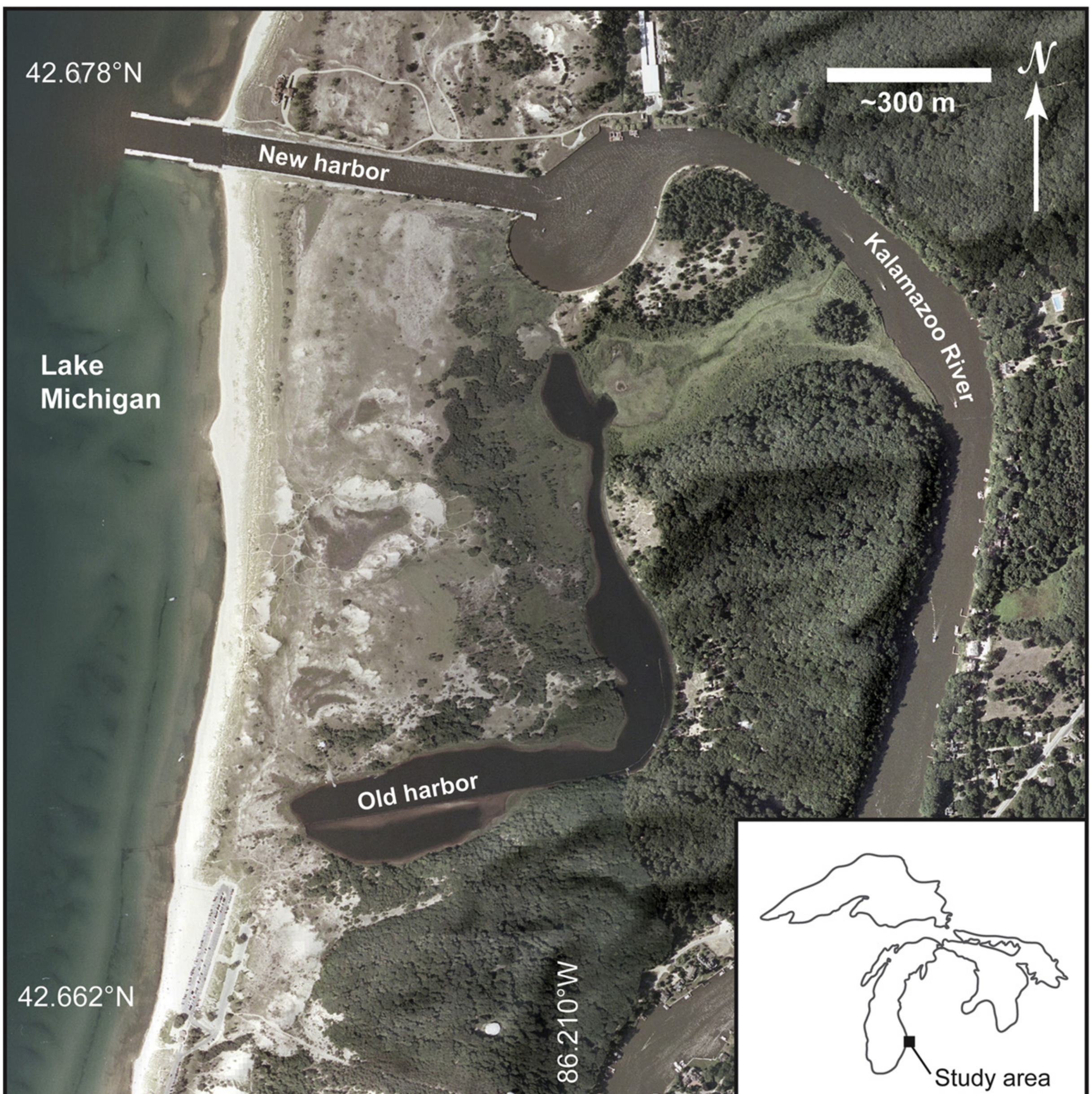

Fig. 1. Study area map indicating the location of the old harbor of the Kalamazoo River where the pier structure, visible as a linear feature in this aerial photograph, was built *ca.* 1870 and the new harbor that was established in the early 1900s. The inset shows the location of the study area within the upper Laurentian Great Lakes region.