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Regional coherency of boreal forest growth defines Arctic driftwood provenancing☆

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ABSTRACT

Arctic driftwood represents a unique proxy archive at the interface of marine and terrestrial environments. Combined wood anatomical and dendrochronological analyses have been used to detect the origin of driftwood and may allow past timber floating activities, as well as past sea ice and ocean current dynamics to be reconstructed. However, the success of driftwood provenancing studies depends on the length, number, and quality of circumpolar boreal reference chronologies. Here, we introduce a Eurasian-wide high-latitude network of 286 ring width chronologies from the *International Tree Ring Data Bank* (ITRDB) and 160 additional sites comprising the three main boreal conifers *Pinus*, *Larix*, and *Picea*. We assess the correlation structure within the network to identify growth patterns in the catchment areas of large Eurasian rivers, the main driftwood deliverers. The occurrence of common growth patterns between and differing patterns within catchments indicates the importance of biogeographic zones for ring width formation and emphasizes the degree of spatial precision when provenancing. Reference chronologies covering millennial timescales are so far restricted to a few larch sites in Central and Eastern Siberia (eastern Taimyr, Yamal Peninsula and north-eastern Yakutia), as well as several pine sites in Scandinavia, where large rivers are missing though. The general good spatial coverage of tree-ring sites across northern Eurasia indicates the need for updating and extending existing chronologies rather than developing new sites.

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1. Introduction

Large boreal river systems are known to transport a large amount of wood timbers into the Arctic Ocean. There, perennial sea ice can prevent some of the logs from sinking and may transport these over thousands of kilometers within the prevailing ocean currents. After several years of sea ice drifting, the wood might be

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deposited at shallow Arctic coastlines along Greenland, Svalbard and Iceland (Hellmann et al., 2013b and references therein). Such Arctic driftwood (ADW) was intensively used by early settlers as the main construction resource and fire fuel, as well as for boat frames, weapons and other tools (Alix, 2005). To date, ADW is still an essential resource in the high-northern latitudes for firewood and to build fences or power poles (Alix and Brewster, 2004; Morris, 1991; Steelandt et al., 2013).

ADW can serve as a basis to potentially reconstruct floods, storms and river bank dynamics, but also climatic conditions such as summer temperature variability in the source areas (Büntgen et al., 2014; Eggertsson, 1994b; Giddings, 1952). Anthropogenic activities including logging and floating are important causes for ADW formation, strongly influencing its species and age composition (Eggertsson, 1993; Hellmann et al., 2015). Dendrochronological assessment of ADW ideally supports the understanding of past settlement history and current activities in northern North America and Siberia (Alix, 2005; Alix and Brewster, 2004).

Within the marine environment, changes in the strength of the Transpolar Drift and the Beaufort Gyre (Morison et al., 2012; Proshutinsky and Johnson, 1997), as well as variations in Arctic sea ice extent were reconstructed (Dyke et al., 1997; England et al., 2008; Funder et al., 2011; Tremblay et al., 1997). Analyses of fossil ADW in the best case even yield insight on past sedimentation processes and hence also on past water temperatures (Selmeier and Grosser, 2011). Techniques for ADW investigation include wood anatomical species identification, tree-ring width (TRW) measurements and radiocarbon dating. Wood identification is essential and should be realized not only macro-, but also microscopically to distinguish on the species-level where possible (i.e. *Pinus*) (Hellmann et al., 2013a). TRW measurements enable dating and also provenancing of ADW, as long as reliable reference chronologies from the boreal forest zone are available and cross-dating is possible (i.e. Eggertsson, 1993; Hellmann et al., 2015; Johansen, 2001; Steelandt et al., 2015). In case long boreal chronologies are missing, radiocarbon measurements are inevitable to estimate the age of old ADW (Dyke and Savelle, 2000; Funder et al., 2011). Beside these classical approaches, further analyses are necessary to achieve more insight in and to understand the complexity of the ADW system. Density measurements of presumably climate sensitive ADW samples should be considered to improve temperature reconstructions (Esper et al., 2012b). Even though studies about the improvement of dendro-provenancing by density measurements are missing, it would most likely not merit the effort due to few reference chronologies.

Driftwood is often affected by fungi, most of them likely already introduced in the origin areas of the trees (comm. R. Blanchette). Survival of these fungi is often limited in high Arctic regions. Analyses of fungi infestation may hence help to clarify duration of ADW deposition times in its source and/or sink areas (Jurgens et al., 2009). Additionally, dendrochronological ADW research can be used to supplement reconstructions of past forest disturbance events (Altman et al., 2014; Chapin et al., 2004).

A precise determination of the age and origin of ADW is, however, indispensable for any further analyses (Hellmann et al., 2015). Since the beginning of ADW research in the late 19th and 20th century (Agardh, 1869; Eurola, 1971; Fischer and Schneider,

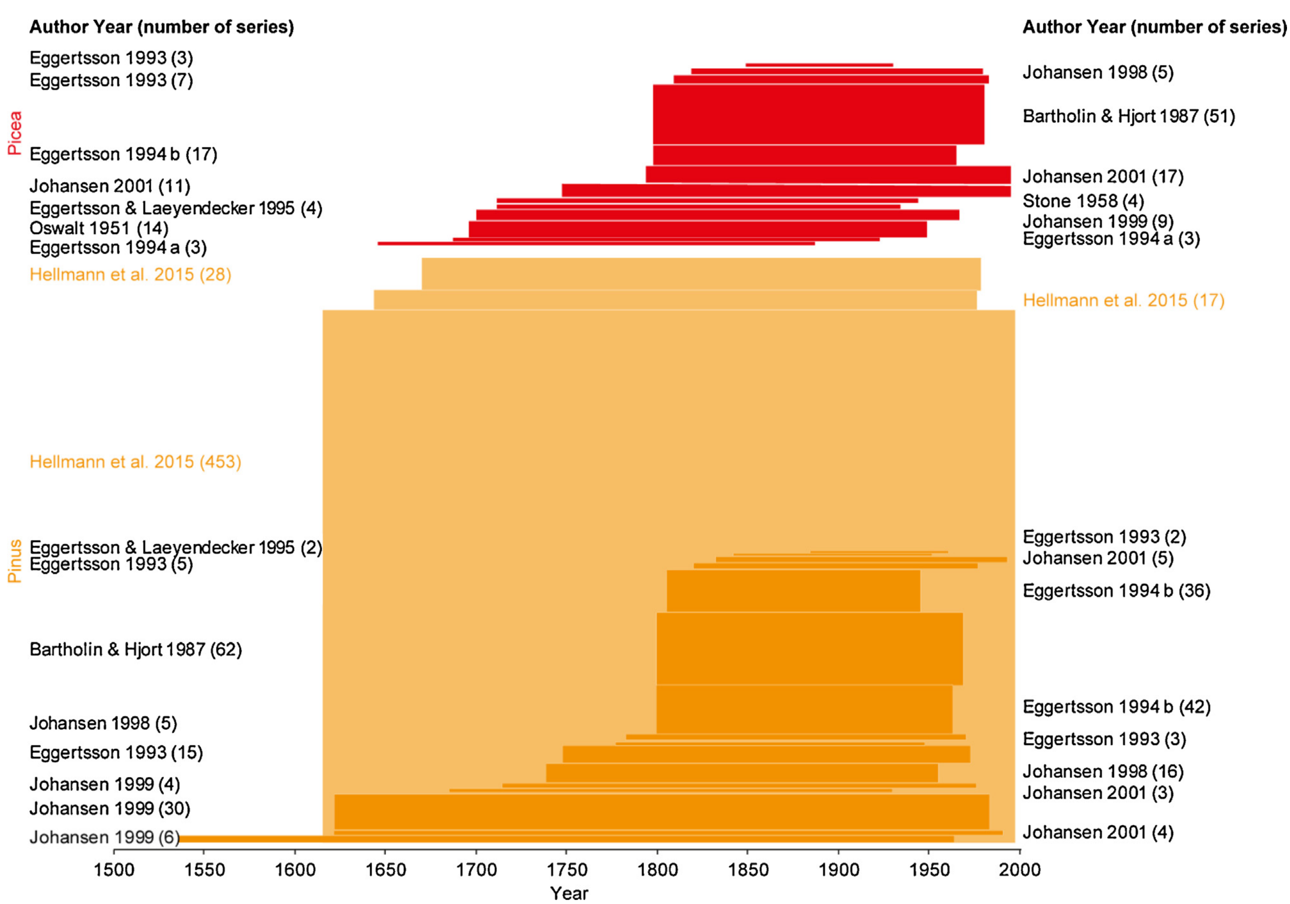

Fig. 1. Dendrochronologically dated ADW series (Bartholin and Hjort, 1987; Eggertsson, 1993, 1994a,b; Eggertsson and Laeyendecker, 1995; Hellmann et al., 2015; Johansen, 1998, 1999, 2001; Oswalt, 1951; Stone, 1958). Each bar represents one absolutely dated ADW chronology. Chronologies of different origin from the same study are displayed as single bars with their height referring to the number of tree-ring width series included.

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