EGU25-2793, updated on 10 Mar 2026
https://doi.org/10.5194/egusphere-egu25-2793
EGU General Assembly 2025

Comprehensive Review of Large Wood in River Restoration Benefits, Risks and Future Directions

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Globally, river ecosystems face severe declines, with freshwater vertebrate populations decreasing by 83% and many species now endangered. Only 14% of rivers in the UK are in good ecological condition, highlighting the urgency for restoration. Large wood (LW) has emerged as a key component in river restoration projects, enhancing geomorphic diversity, habitat heterogeneity, and biodiversity. Historically removed as "debris", its reintroduction is now essential for restoring natural river processes and creating diverse habitats for aquatic life. Despite the broad use of LW in river restoration, little is known about its effectiveness and suitability for different contexts. Therefore, this comprehensive review has been conducted to identify current knowledge gaps, examining the reliance expert judgment commonly used in restoration practice.

The review highlighted that most studies are concentrated in the US, the UK, and Australia. Temporal trend demonstrates a noticeable increase in studies starting around 2014. The types of LW structures employed in real-world river restoration project were also analysed. Surprisingly, more than 40% of the reviewed papers did not specify the exact configurations of the studied LW structures, referring only to "large wood" in general terms. When reported, the most frequently studied LW structures were LW jams, followed by single logs. However, a significant gap in the literature is the lack of detailed descriptions regarding the specific configurations of LW structures and how this affects restoration efforts. Field monitoring is also a widely used method, however, only two studies included long-term monitoring (10 to 20 years). The number of studies utilising numerical modelling is notably low, and the absence of artificial intelligence (AI) methodologies is also apparent. Also, this review revealed that the existing literature has a clear focus on lowland, low-energy river systems. Many of these rivers were classified within 2nd to 4th orders, indicating smaller to medium-sized tributaries.

The quantitative analysis of LW interventions highlights their diverse impacts. For example, LW dams, deflectors, and V-shaped structures can lead to a marked increase in pools, with coverage rising from 11% to 27% immediately after restoration, unlike single LW elements, which reported no statistically significant changes. Other effects are also evident: hydraulic retention time increased by up to 67.8%, whereas flow and morphological diversity increased by several orders of magnitude than pre-restoration conditions. These changes also saw a 35% rise in macroinvertebrate diversity and a tenfold increase in fish abundance, showcasing cascading ecological benefits. These findings underscore the multifaceted benefits of LW structures,

particularly in promoting channel recovery, enhancing hydraulic and habitat diversity, and supporting habitat restoration over the long term.