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Why wood should move in rivers

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Abstract

Large wood is inherently mobile in naturally functioning river corridors, yet river management commonly introduces wood that is anchored to limit hazards. Wood that is periodically mobilized is important for: replacing stationary large wood that performs diverse physical and ecological functions; contributing to the disturbance regime of the river corridor; diversifying wood decay states; dispersing organisms and propagules; providing refugia during floodplain inundation and in mobile-bed channels; dissipating flow energy; and supplying wood to downstream environments including lakes, coastlines, the open ocean, and the deep sea. We briefly review what is known about large wood mobility in river corridors and suggest priorities for ongoing research and river management, including: structural designs that can pass mobile wood; enhancing piece diversity of introduced wood that is anchored in place; quantifying wood mobilization and transport characteristics in natural and managed river corridors; and enhancing documentation of the benefits of wood mobility.

KEYWORDS

large wood, river corridor, wood decay, wood mobility, wood transport, wood transport

1 | INTRODUCTION

Large wood (≥10 cm diameter, 1 m length) is inherently mobile in river corridors over diverse temporal and spatial scales (Comiti et al., 2016; Kramer & Wohl, 2017; Ruiz-Villanueva et al., 2016). Within the river corridor of active channel(s) and floodplain, wood is episodically recruited, transported laterally and downstream, and deposited for varying lengths of time (Benda & Sias, 2003; Kramer & Wohl, 2017; Ruiz-Villanueva et al., 2016). Wood mobility has been studied via flume experiments (e.g., Bertoldi et al., 2014), tags (e.g., MacVicar et al., 2009; Ravvazolo et al., 2015), videos (e.g., MacVicar & Piégay, 2012), time-interval photos (Kramer & Wohl, 2014), repeat remote imagery (e.g., Lassettre et al., 2008), pre- and post-flood (e.g., Pellegrini et al., 2022) or runoff season (Wohl & Goode, 2008; Wohl et al., 2022) surveys, and numerical modeling (e.g., Persi et al., 2020; Ruiz-Villanueva et al., 2014). This body of research supports at least preliminary characterizations of wood mobility patterns (e.g., Kramer & Wohl, 2017), but much more remains to be done.

The great majority of scientific literature on wood in rivers addresses stationary wood (e.g., Ruiz-Villanueva et al., 2016; Swanson et al., 2021; Wohl, 2017). Stationary wood creates heterogeneity in hydraulics, biogeochemical reactions, sediment dynamics, river corridor morphology, habitat, and food resources for aquatic and riparian communities (Gregory, Boyer, & Gurnell, 2003; Wohl, 2017).

Mobile wood, although less commonly studied than stationary wood, is likely also necessary for maintaining diverse forms of heterogeneity within river corridors. We define mobile wood as any piece(s) of large wood that is actively in transport. In naturally functioning river corridors, most pieces of large wood alternate through time between relatively long periods of being stationary and briefer periods of mobility. We draw a distinction here between mobile and stationary wood because river management is likely to prioritize artificial stabilization of wood.

By moving, wood creates physical disturbances that directly alter river corridor morphology and biotic communities. Wood movement is thus analogous to fluctuations in discharge and sediment supply that create a disturbance regime and maintain a shifting habitat mosaic (Stanford et al., 2005). Wood movement also redistributes individual wood pieces within the river corridor, helping to maintain heterogeneity of piece size and decay state, as well as position and associated physical and ecological functions of the wood.

Recognition of the fundamental role of wood in forested river corridors has led to increased use of wood in river management and restoration. Much of this management, however, seeks to stabilize existing or introduced wood (Abbe et al., 2003; Grabowski et al., 2019; Roni et al., 2015) because of (i) concerns with hazards resulting from mobile wood that can accumulate on or physically damage infrastructure, such as bridge piers (De Cicco et al., 2018; Panici et al., 2020; Schalko et al., 2020a, 2020b) or reservoirs (Furlan et al., 2018); (ii) hazards for commercial riverine or coastal navigation (e.g., Doong et al., 2011) or recreational river use (Conley & Kramer, 2020); or (iii) a desire to sustain wood functions at the site of emplacement in managed river corridors that may have limited wood recruitment and natural wood-trapping sites. Although we recognize that existing or introduced wood must be stabilized in some settings, we contend that mobile wood is a key part of the natural disturbance regime in forested watersheds, as well as providing other riverine functions, and that therefore river management should place greater emphasis on sustaining wood mobility. Our objectives in this paper are to review what is known about the benefits of mobile wood and to identify research and management knowledge gaps regarding wood mobility.

2 | STATE OF SCIENCE REGARDING WOOD MOBILITY IN RIVER CORRIDORS

Gurnell (2007) highlights analogies between the movement of mineral sediment and movement of large wood in rivers. River flows or debris flows can move wood within river corridors (Figure 1). River flows can transport wood in suspension (floating) or in contact with the channel bed (sunken). Individual pieces can move without piece-to-piece interactions during uncongested transport, or numerous pieces can form congested transport in which logs move together as a single mass and occupy more than a third of the channel area, with semi-congested transport as an intermediate transport regime (Braudrick et al., 1997). Hypercongested wood transport occurs during highly unsteady wood-laden flows with non-uniform log motion (Ruiz-Villanueva et al., 2019). Investigators have long inferred that pieces that are short relative to channel width and narrow relative to flow depth are most mobile (e.g., Gurnell et al., 2002), but relatively recent direct observations of wood mobility have refined these inferences.

In a comprehensive synthesis of wood mobility studies, Kramer and Wohl (2017) distinguished small rivers (key piece wood length > channel width; diameter of logs > flow depth), medium rivers (length of key logs ≥ channel width; log diameter ~ flow depth), and large and great rivers (all wood lengths < channel width; log diameter << flood depth). These distinctions reflect consistently different patterns in wood mobility and deposition, as summarized in the list of common observations in Table 1 synthesized from Kramer and Wohl (2017, Tab. 2, 3, and 4). The primary observation across diverse studies is that wood transport in natural rivers exhibits high spatial and temporal variability, but consistent patterns facilitate at least broad predictions (Kramer & Wohl, 2017) (Figure 2).

3 | BENEFITS DERIVED FROM MOBILE WOOD

Our review of the literature on large wood in river corridors suggests at least seven basic functions that derive from the presence of large mobile wood (Figure 3). We distinguish these as benefits derived during wood transport and as benefits deriving from wood transport and briefly discuss each of these below.

3.1 | Benefits derived during wood transport

3.1.1 | Organism and propagule dispersal

Mobile wood pieces assist the dispersal of soil arthropods (Coulson et al., 2002), estuarine gastropods (Kano, Fukumori, Brenzinger, & Waren, 2013), amphipods (Wildish, 2012), and a wide variety of fungi and freshwater and marine invertebrates (Thiel & Gutow, 2004) from river networks into and within ocean basins. This is also likely true for rivers but has not yet been studied. Numerous factors can enhance biodiversity, but the ability of organisms to reach new habitats is critical to sustaining biodiversity (e.g., Trakhtenbrot et al., 2005).

Although river flow inherently provides at least downstream dispersal, dispersal within the flow can be accompanied by stresses, such as those associated with mobile substrate and high suspended sediment concentrations for aquatic invertebrates (Haden et al., 1999; McKenzie et al., 2020), as well as prolonged submergence for fungi and terrestrial organisms (Coulson et al., 2002). Floating wood can provide dispersal while minimizing some of these stressors. Ultimately, mobile wood as a dispersal mechanism can enhance survival, maintain gene flow, and ensure continued colonization of species in estuarine, oceanic, and transoceanic environments.

3.1.2 | Refugia during floodplain inundation and in mobile-bed channels

Examining forested floodplains in the southeastern United States, Braccia and Batzer (2001) found that floating wood forms a hot spot for invertebrate richness and arthropod biomass during periods of floodplain inundation. Ballinger, Lake, and MacNally (2007) documented a similar function for terrestrial invertebrates in southeastern Australian floodplains. Floating wood can also provide an important substrate for macroinvertebrates in desert rivers with high suspended sediment concentrations and limited cobble substrate (Haden et al., 1999). Thus, mobile wood provides a substrate that can facilitate increased diversity and abundance of both aquatic and terrestrial invertebrates, which is an important indicator of habitat quality and is critical for nutrient cycling, decomposition, and overall trophic function. Because different functional groups of benthic macroinvertebrates influence stream biofilms and organic matter dynamics and are preyed upon by fish and other animals, maintaining diversity within river macroinvertebrate communities is critical for sustaining diverse trophic cascades and resilience in stream ecosystems (e.g., Elmqvist et al., 2003).

3.1.3 | Dissipation of flow energy

The tendency of stationary large wood to increase hydraulic roughness and flow resistance is well documented (e.g., Curran & Wohl, 2003; Daniels & Rhoads, 2004; Shields & Smith, 1992). Although investigators have not quantified the effects of mobile large wood on dissipation of flow energy, entrainment and transport of wood certainly require energy. Consequently, large wood in transport presumably reduces the level of energy available for other forms of hydraulic work such as sediment entrainment and transport and may thus exert indirect geomorphic effects on hydraulic work in river corridors.

3.2 | Benefits deriving from the presence of mobile large wood

3.2.1 | Replenishment of stationary large wood

Logjams and individual wood pieces create multiple physical and ecological benefits in river corridors (Livers & Wohl, 2021), including:

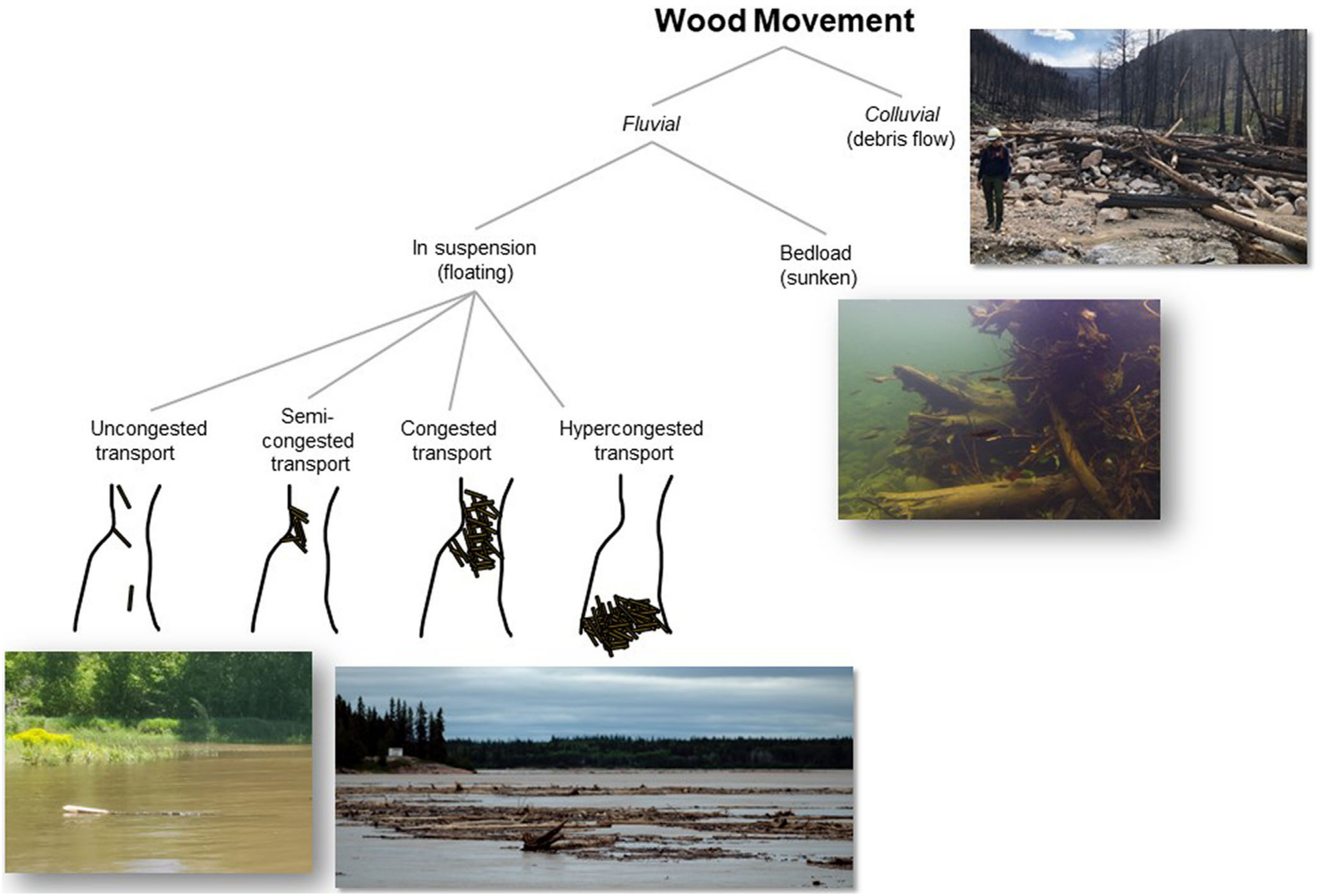

FIGURE 1 Different modes of wood movement by colluvial and fluvial processes. Inset photo at upper right of wood transported by debris flow courtesy of Francis Rengers. Inset photo at lower right of congested wood transport on the Slave River, Canada courtesy of Natalie Kramer. [Color figure can be viewed at wileyonlinelibrary.com]

TABLE 1 Commonly observed characteristics of large wood mobility, as discussed in greater detail in Kramer and Wohl (2017).

Characteristics of large wood mobility	Sample references
Wood mobilization thresholds & hysteresis in transport	
Wood mobilization thresholds • Exist at magnitudes less than bankfull • Before the threshold, transport is negligible • After the threshold, transport is possible & increases linearly with discharge until an upper wood transport rate associated with overbank flows is reached, at which point wood transport suddenly decreases or levels off	Kramer and Wohl (2017)
Hysteresis in wood transport • Mobilization of wood occurs on the rising limb & is comparatively negligible on the falling limb • Flows of equal magnitude transport much less wood on the falling limb than on the rising limb • Wood in transport on the falling limb is rapidly retained & entrapped • Short pieces are transported on the rising & falling limbs, whereas the largest pieces are mainly transported on the rising limb • Shorter pieces are transported earlier on the rising limb & follow a consistent relation with discharge; larger pieces are mobilized after small pieces & do not correlate well with discharge • Most wood is deposited near peak flow magnitude • Wood recruited during the falling limb originates from morphological changes of the channel (e.g., bank erosion)	MacVicar et al., (2009), MacVicar and Piégay (2012), and Ravvazolo et al., (2015)
Influences on wood mobility	
The role of channel size • in small streams, the frequency of extreme events governs wood transfer downstream, with cycling of wood storage related to recurrence intervals of debris flows • in medium rivers, yearly flows re-organize individual pieces of wood into jam stable states, whereas exceptional floods reorganize jams • in large rivers, reach-scale wood storage can be highly variable year to year, & depends on flows during prior years • Median mobilization rates increase with increasing channel size, but maximum mobilization rates are greatest in medium-sized channels	Kramer and Wohl (2017)
The role of channel morphology: Wood will be routed more quickly and stored for shorter time spans in river corridors that are • Confined (vs. laterally unconfined) • Single-thread (vs. multi-thread) • Higher gradient (vs. lower downstream gradient) • With smaller variability in channel depths of the flooded cross-section	Wyżga and Zawiejska (2005) and Wohl and Iskin (2022)
The role of flood magnitude and hydrograph shape • The largest wood fluxes on rivers of all sizes occur during infrequent high flows • Flashier, more steeply rising hydrographs mobilize more wood • Wood transport responds non-linearly to increases in flow magnitudes & is highly variable • Most wood is transported during relatively infrequent high flows, but annual floods can still mobilize wood at lower rates (typically <30%) in many rivers	Schenk et al., (2014) and Kramer et al., (2017)
The role of flow history • The amount of wood available for transport during any flood is a function of past flow history and non-fluvial recruitment since the last wood-transporting flow • Flood peaks of similar magnitude will have varying wood loads based on their position in a sequence of floods	Haga et al., (2002) and Kramer et al. (2017)
The role of wood recruitment • Newly recruited wood is less stable & moves greater distances downstream than previously transported wood • Newly recruited wood can reorganize into jam stable states after only one bankfull flow; jams are re-mobilized and re-organized during exceptional flows • A threshold wood input rate governs transition between congested & uncongested transport	Braudrick et al. (1997) and Kramer and Wohl (2017)
Effects of wood piece characteristics & spatial organization on wood mobility • Anchoring (e.g., partial burial, bracing against obstructions) is the most important variable governing initial wood mobilization • Presence of a rootwad limits initial mobilization & travel distance	Braudrick and Grant (2000), Wohl and Goode (2008), and Kramer and Wohl (2017)

(Continues)

TABLE 1 (Continued)

Characteristics of large wood mobility	Sample references
• A length mobility threshold exists near or above bankfull width • A depth threshold of ~0.5 log diameter exists when flow depths = critical floating depth related to piece diameter and density • Wood pieces in jams are less mobile than individual pieces • Most logjams are mobilized by channel change or failure of key pieces during high flows, but commonly reform in the same location with new pieces • Wood transport velocity is more significantly related to log volume than magnitude of floods • Wood with greater density is less readily mobilized	

- increased substrate and hydraulic diversity (Buffington & Montgomery, 1999),
- greater pool volume in channels (Richmond & Fausch, 1995),
- increased hyporheic exchange (Doughty et al., 2020; Hester & Doyle, 2008),
- retention of particulate organic matter (Livers et al., 2018),
- increased channel-floodplain connectivity (Jeffries et al., 2003),
- the potential for nonlinear complexity (Phillips, 2003) of riverine processes and forms, as for example when logjams facilitate formation of a multi-thread channel planform (Collins et al., 2012; Wohl, 2011) that includes secondary channels with varying degrees of connectivity and diverse habitat,
- habitat for floodplain organisms that live on or use large wood (Osei et al., 2015; Pettit et al., 2005), and
- greater patch diversity in floodplains (Collins et al., 2012).

Although these benefits derive from at least temporarily stable wood pieces and logjams, multiple studies indicate that individual wood pieces, wood pieces within logjams, and entire logjams can be removed during high flows (Curran, 2010; Manners & Doyle, 2008; Wohl & Iskin, 2022; Wohl & Scamardo, 2021). Maintaining and replacing wood pieces and logjams therefore requires a continuing supply of mobile wood that can be trapped and stored at sites with limited wood transport. In addition to the benefits derived from replacement of stationary large wood in naturally functioning river corridors, continuing wood input from mobile pieces may be critical to sustaining the function of restoration projects that use non-anchored wood pieces.

Even if wood pieces do not move, lateral movement of the channel (e.g., Collins et al., 2012) or aggradation of the channel bed or floodplain surface can bury large wood and eliminate its benefits for surface processes. Consequently, a continuing supply of mobile wood

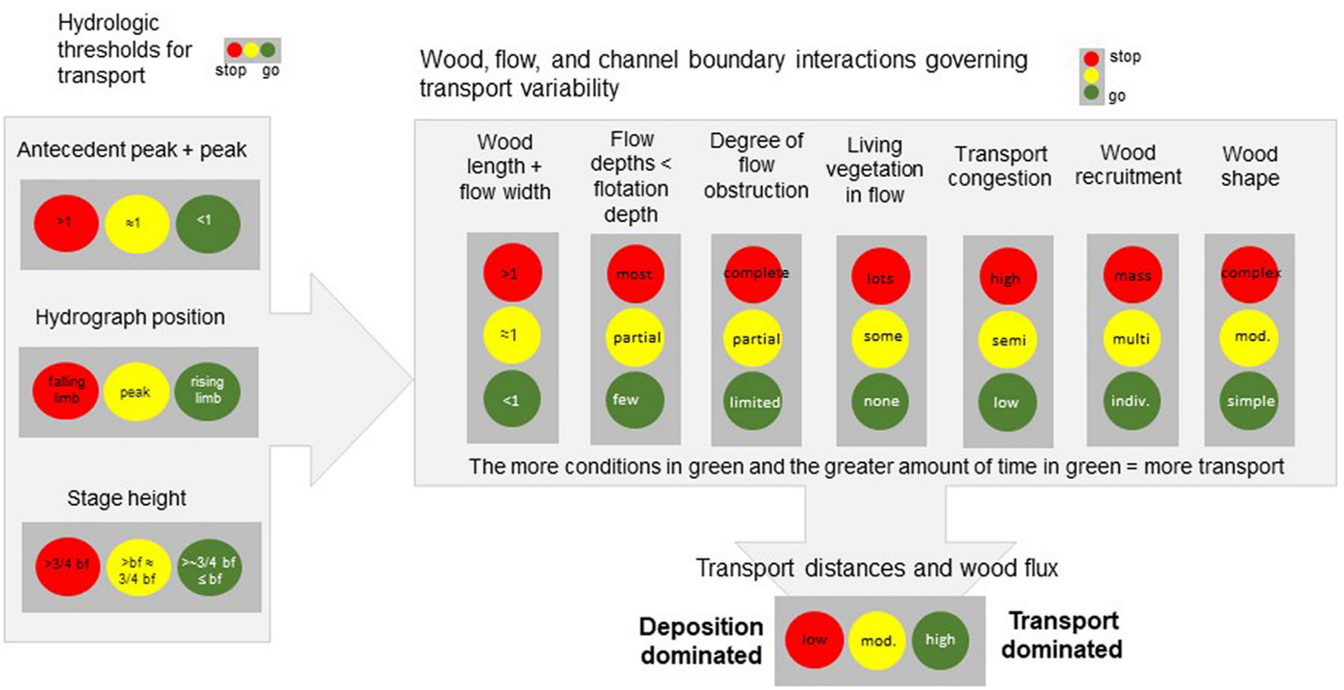

FIGURE 2 Schematic illustration of the effects of the characteristics of flow, wood pieces, and wood recruitment on relative wood mobility. Modified from Kramer & Wohl, 2017, fig. 10. [Color figure can be viewed at wileyonlinelibrary.com]

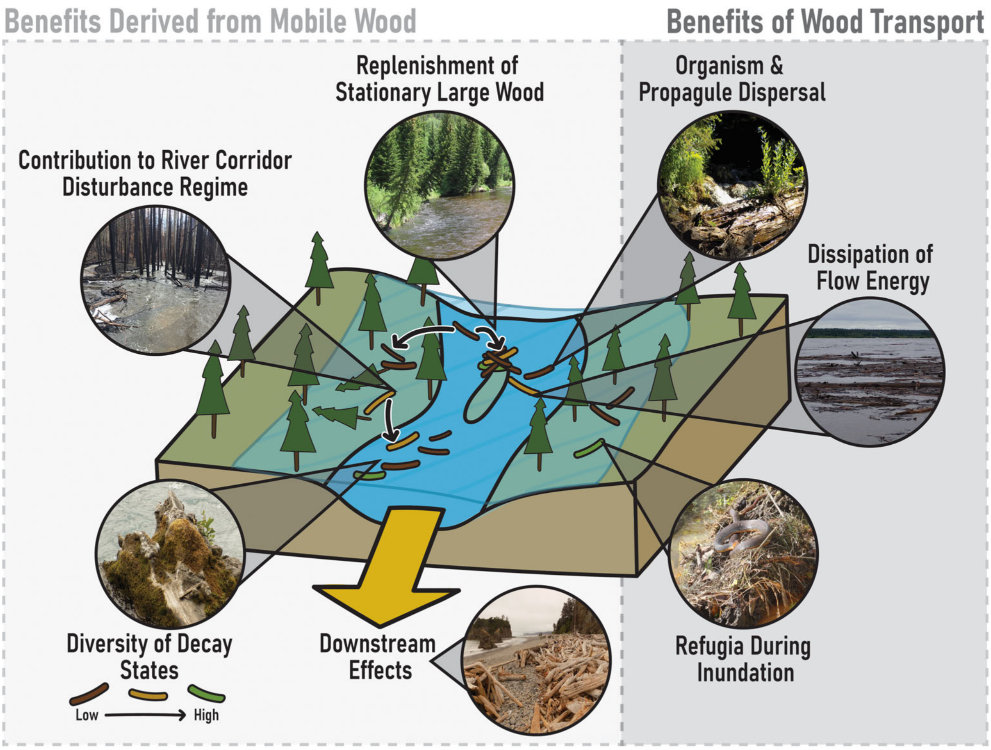

FIGURE 3 Schematic illustration of the benefits derived from mobile wood. Inset photo for dissipation of flow energy courtesy of Natalie Kramer. [Color figure can be viewed at wileyonlinelibrary.com]

is necessary to ensure ongoing trapping and storage of new wood. This may be particularly important in rapidly changing sand-bed channels in which wood pieces provide important stationary substrate for macroinvertebrates (e.g., Johnson et al., 2003; Pilotto et al., 2016; Wallace & Benke, 1984) or create sufficient channel-boundary roughness to ensure sediment trapping (Brooks et al., 2003). Replenishment of wood supply is also particularly important for floodplains where wood accumulations provide preferred germination sites for riparian vegetation (e.g., Pettit et al., 2006), but high wood decay rates limit the persistence of these accumulations. Fundamentally, maintaining wood mobility is likely vital to maintaining a dynamic equilibrium in reach-scale wood budgets (Wohl et al., 2019).

3.2.2 | Contribution to the river corridor disturbance regime

Ecologists describe the importance of patch dynamics within the active channel (Pringle et al., 1988) and a shifting habitat mosaic as channel and floodplain habitat patches change in space and time (Arscott et al., 2002; Bormann & Likens, 1979; Nakamura et al., 2007; Stanford et al., 2005). Floods are widely recognized to drive spatial and temporal variation in the size, juxtaposition, and diversity of habitat patches in river corridors, but other disturbances, such as wildfire (Kleindl, Rains, Marshall, & Hauer, 2015) or fluctuations in sediment supply that drive channel changes (e.g., Constantine et al., 2014; Kemper et al., 2022) can also create and maintain patch diversity.

Mobile wood can damage or remove riparian vegetation (e.g., Johnson et al., 2000) and stationary wood within the river corridor, as well as influence lateral channel movement and associated channel and floodplain spatial heterogeneity (Collins et al., 2012; Montgomery & Abbe, 2006; Naiman et al., 2010). Movement of stationary wood, especially wood within logjams, can create downstream pulses of stored sediment and organic matter (Adenlof & Wohl, 1994; Bugosh & Custer, 1989; Umazano & Melchor, 2020). In addition, stationary wood pieces or logjams create erosional and depositional effects that may change through time while the wood is present or even after flow removes the wood from the site. These erosional and depositional effects include: the formation and enlargement of bars (Gurnell et al., 2005) and secondary channels (Wohl, 2011); the accretion of bars to floodplains (Collins et al., 2012); alteration of meander geometry and rate of meander migration (Daniels & Rhoads, 2004); channel avulsion (Brummer et al., 2006); and the formation of backwater and scour pools and patches of finer sediment (Buffington & Montgomery, 1999) and coarse particulate organic matter (Beckman & Wohl, 2014). The diverse parafluvial and riparian surfaces created by wood in turn host diverse soils and vegetation communities (Collins et al., 2012; Francis et al., 2008; Gurnell et al., 2005). The ongoing removal of existing wood, along with replacement of that wood or redistribution of newly deposited wood, together help to maintain these dynamic habitat patches (Maggliozi et al., 2019). Consequently, mobile large wood forms a part of the natural disturbance regime in forested river corridors.

3.2.3 | Diversity of decay states

The diversity of decay states in stationary large wood in the active channel(s) (Collier, 2014; Harmon et al., 1986; O'Connor, 1992) and in the floodplain (Ballinger et al., 2010; Braccia & Batzer, 2001) increases habitat diversity for a variety of organisms. Maintaining a continuing supply of wood to depositional sites in the river corridor can help to sustain wood pieces with diverse decay states, especially in climates such as the humid and seasonal tropics that promote rapid wood decay (Clark et al., 2002) and for tree species with relatively fast decay rates. Globally, angiosperm wood decays faster than gymnosperm wood within shared sites (Weedon et al., 2009), so that genera such as *Alnus*, *Betula*, *Populus*, and *Salix* decay more rapidly than *Pinus* or *Abies* (Freschet et al., 2012).

3.2.4 | Downstream effects

Large wood transported into lakes, coastal areas, the open ocean, and the deep seafloor provides a diverse array of ecosystem services (Wohl & Iskin, 2021), and the continuation of these services depends on a continuing supply of wood from uplands via riverine transport.

Wood creates habitat for many types of aquatic organisms in lakes by providing substrate favored by algae and insect larvae and shelter for small fish (Marburg et al., 2006). The greater complexity of littoral zones in lakes with large wood contributes to greater productivity of fish communities and can enhance carbon sequestration and nutrient fluxes in nearshore areas (Czarnecka, 2016). Wood along lakeshores can also help to trap eolian and lake-transported sediment and provide preferential sites for plant germination, enhancing lakeshore progradation and creating distinctively patterned shoreline vegetation communities (Kramer & Wohl, 2015).

Analogously, wood carried down rivers and deposited along marine coastlines and estuaries (i.e., driftwood) influences physical and ecological processes. Wood deposited on coastlines can help to trap and retain mobile sediment, reducing coastal erosion rates (Eamer & Walker, 2010) and facilitating the formation of sand dunes (Heathfield & Walker, 2011) and taller berm crests on gravel beaches (Kennedy & Woods, 2012). Driftwood on sandy coastlines can enhance native plant abundance and richness (Dugan & Hubbard, 2010), help to retain organic matter, and provide nutrients and habitat for multiple species of invertebrates (Gheskiere et al., 2005). Wood in rocky intertidal zones provides nutrients, habitat, and refuge from predation for invertebrates (Kano et al., 2013; Storry et al., 2006). Wood influences vegetation zonation in tidal marshes (Hood, 2007), as well as carbon storage, nutrient retention, and vegetation growth in mangrove forests (Krauss et al., 2005). Driftwood in the ocean provides an important transport mechanism for fungi (Blanchette et al., 2016), bryozoa, and diverse invertebrates (Gracia et al., 2018), as well as critical habitat for multiple fish species (Caddy & Majkowski, 1996; Gooding & Magnuson, 1967). Marine benthic systems benefit from wood-derived nutrients and habitat (Fagervold et al., 2012; McLeod & Wing, 2007), and wood falling to the ocean floor may help to establish sunken-wood communities and other chemosynthetic faunas in the deep sea (Distel et al., 2000; Kano et al., 2013).

In addition to these documented benefits associated with the presence of mobile wood in river corridors, we infer that mobile wood may be an important contributor to abrasion and breakage of wood in decay-limited environments such as hot and cold deserts (Harmon et al., 1986; Wohl, 2017). Even in wetter climates with more rapid wood decay, breakage is more likely than decay to create a substantial reduction in wood density, branching complexity, and piece size (Merten et al., 2013). Limited analysis of fine particulate organic matter in streams suggests that a substantial portion may be derived from decay, breakage, and abrasion of large wood. Examining a forested stream in western Oregon, for example, Ward and Aumen (1986) found that most fine particulate organic matter is derived from wood. This material is a key part of the food web in forested streams with primary production from instream photosynthetic plants (Tank et al., 2010). Wood also contributes to coarse particulate organic matter, which can have more carbon- and nitrogen-rich constituents and labile properties than fine particulate organic matter (Johnson et al., 2018). Particulate organic matter also exerts an important influence on the porosity, total volume, and effective surface area, and therefore the drag force exerted on and backwater storage created by, logjams (Livers et al., 2020; Livers & Wohl, 2021; Manners et al., 2007).

4 | FUTURE DIRECTIONS OF MOBILE WOOD RESEARCH AND PRACTICE

Gaps in our understanding of mobile wood indicate the need to provide greater insight into questions surrounding wood movement across systems. We suggest that prioritizing research in the following areas can improve understanding of mechanisms of wood mobilization and transport: (i) quantitative data on wood mobilization and transport distance, frequency of mobilization, and duration of mobility in natural and managed river corridors; and (ii) documenting and quantifying the benefits of wood mobility discussed earlier, particularly across a range of hydroclimatic regimes, geographic areas, and river process domains. Integral to both of these suggestions is the need to enhance understanding of wood budgets over time spans longer than a year or a few years. Developing longer term datasets of wood dynamics on diverse rivers that employ consistent measurements across studies would be ideal. Decadal (Wohl & Iskin, 2022; Wohl & Scamardo, 2021) and multidecadal studies of wood dynamics that have recently been published (Goodman et al., in press; Lininger & Hilton, 2022) help to address this gap. Beyond direct field measurements of wood presence/absence over many years, indirect approaches including physical experiments, numerical modeling, and radiocarbon or other chronologies of wood ages can also provide insight into multidecadal wood movement.

In river management where only fixed wood is used, some of the benefits associated with mobile wood can be mimicked by deliberately employing wood with varying piece characteristics, including piece size, piece complexity (branching, rootwads), and decay state, as well as wood pieces representing different species native to the watershed. Large wood can be recruited naturally from diverse sources that vary in importance across time and space. These sources include hillslope mass movements, bank erosion, fluvial transport from upstream sites, exhumation of wood buried in the floodplain, and individual or mass (e.g., wildfire, blowdown) mortality of trees within the river corridor (Benda & Sias, 2003; Wohl, 2020). In managed river corridors with limited wood recruitment, river restoration can enhance recruitment over the short term by adding unstabilized large wood to floodplains and, over longer timescales, by protecting forest regeneration.

Attention to the relative rates of wood recruitment and wood transport may be particularly important in managed river corridors, where wood stabilization may be warranted if wood recruitment is absent. Managed river corridors are more likely to have regulated flow and simplified channel morphology, as well as a lack of wood recruitment, all of which can result in rapid mobilization and transport of wood deliberately introduced for management. Introduced wood may thus have residence times too short to provide the desired benefits.

We suggest that prioritizing field experiments and river restoration that includes monitoring in the following areas can improve the opportunities for and acceptance of maintaining or restoring the presence of mobile wood in managed river corridors:

- emphasizing structural designs that can pass mobile wood in river corridors (De Cicco et al., 2018; Schalko et al., 2020a); and
- introducing diverse (size, shape, decay) pieces or accumulations of anchored wood.

5 | CONCLUSIONS

Our primary contention in this paper is not that wood fixed in place cannot provide valuable functions in river corridors. Instead, we contend that anchored wood is a limited substitute for naturally mobile wood and should be used as a last resort in river management and restoration. Within the past few years, river restoration has begun to introduce substantial quantities of potentially mobile wood that are then redistributed by varying flows and channel adjustments (Deer Creek, 2022; Hinshaw et al., 2022). Riverine scientists have increasingly recognized the importance of a natural disturbance regime associated with spatially and temporally variable fluxes of water and sediment through river corridors (Poff et al., 1997; Wohl et al., 2015) and the associated continual adjustments in riverine forms (e.g., Florsheim, Mount, & Chin, 2008). Investigators have also documented the many beneficial effects of continuing wood fluxes in coastal and marine environments. Consequently, we propose that preserving wood mobility within forested river corridors is analogous to preserving a natural flow regime via environmental flows (Gerten et al., 2013; Tharme, 2003) or a balanced sediment regime via sediment augmentation or bypassing (Kondolf et al., 2014; Mörtl & De Cesare, 2021).

Overall, we advocate for prioritizing research and field experiments that examine the benefits of mobile wood, as well as increasing the implementation and monitoring of river restoration practices that introduce and promote heterogeneity in wood pieces and piece mobility. Such endeavors can improve the opportunities for, and acceptance of, maintaining, restoring, or utilizing the presence of mobile wood in managed river corridors.

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DATA AVAILABILITY STATEMENT

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

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REFERENCES

Abbe, T. B., Brooks, A. P., & Montgomery, D. R. (2003). Wood in river rehabilitation and management. In S. V. Gregory, K. L. Boyer, & A. M. Gurnell (Eds.), *The ecology and Management of Wood in world Rivers* (pp. 367–389). Bethesda, MD: American Fisheries Society.

Adenlof, K. A., & Wohl, E. E. (1994). Controls on bedload movement in a subalpine stream of the Colorado Rocky Mountains, USA. *Arctic and Alpine Research*, *26*, 77–85.

Arscott, D. B., Tockner, K., van der Nat, D., & Ward, J. V. (2002). Aquatic habitat dynamics along a braided alpine river ecosystem (Tagliamento River, Northeast Italy). *Ecosystems*, *5*, 802–814.

Ballinger, A., Lake, P. S., & MacNally, R. (2007). Do terrestrial invertebrates experience floodplains as landscape mosaics? Immediate and longer-term effects of flooding on ant assemblages in a floodplain forest. *Oecologia*, *152*, 227–238.

Ballinger, A., MacNally, R., & Lake, P. S. (2010). Decay state and inundation history control assemblage structure of log-dwelling invertebrates in floodplain forests. *River Research and Applications*, *26*, 207–219.

Beckman, N. D., & Wohl, E. (2014). Carbon storage in mountainous headwater streams: The role of old-growth forest and logjams. *Water Resources Research*, *50*, 2376–2393.

Benda, L. E., & Sias, J. C. (2003). A quantitative framework for evaluating the mass balance of in-stream organic debris. *Forest Ecology and Management*, *172*, 1–16.

Bertoldi, W., Welber, M., Mao, L., Zanella, S., & Comiti, F. (2014). A flume experiment on wood storage and remobilization in braided river systems. *Earth Surface Processes and Landforms*, *39*, 804–813.

Blanchette, R. A., Held, B. W., Hellmann, L., Millman, L., & Buntgen, U. (2016). Arctic driftwood reveals unexpectedly rich fungal diversity. *Fungal Ecology*, *23*, 58–65.

Bormann, F. H., & Likens, G. E. (1979). Catastrophic disturbance and the steady state in northern hardwood forests: A new look at the role of disturbance in the development of forest ecosystems suggests important implications for land-use policies. *American Scientist*, *67*, 660–669.

Braccia, A., & Batzer, D. P. (2001). Invertebrates associated with woody debris in a southeastern U.S. forested floodplain wetland. *Wetlands*, *21*, 18–31.

Braudrick, C. A., & Grant, G. E. (2000). When do logs move in rivers? *Water Resources Research*, *36*, 571–583.

Braudrick, C. A., Grant, G. E., Ishikawa, Y., & Ikeda, H. (1997). Dynamics of wood transport in streams: A flume experiment. *Earth Surface Processes and Landforms*, *22*, 669–683.

Brooks, A. P., Brierley, G. J., & Millar, R. G. (2003). The long-term control of vegetation and woody debris on channel and flood-plain evolution: Insights from a paired catchment study in southeastern Australia. *Geomorphology*, *51*, 7–29.

Brummer, C. J., Abbe, T. B., Sampson, J. R., & Montgomery, D. R. (2006). Influence of vertical channel change associated with wood accumulations on delineating channel migration zones, Washington, USA. *Geomorphology*, *80*, 295–309.

Buffington, J. M., & Montgomery, D. R. (1999). Effects of hydraulic roughness on surface textures of gravel-bed rivers. *Water Resources Research*, *35*, 3507–3521.

Bugosh, N., & Custer, S. G. (1989). The effect of a log-jam burst on bedload transport and channel characteristics in a headwater stream. In D. F. Potts & W. W. Woessner (Eds.), *Headwaters hydrology* (pp. 203–211). Bethesda, MD: American Water Resources Association.

Caddy, J. F., & Majkowski, J. (1996). Tuna and trees: A reflection on a long-term perspective for tuna fishing around floating logs. *Fisheries Research*, *25*, 369–376.

Clark, D. B., Clark, D. A., Brown, S., Oberbauer, S. F., & Veldkamp, E. (2002). Stocks and flows of coarse woody debris across a tropical rain forest nutrient and topography gradient. *Forest Ecology and Management*, *164*, 237–248.

Collier, K. J. (2014). Wood decay rates and macroinvertebrate community structure along contrasting human pressure gradients (Waikato, New Zealand). *New Zealand Journal of Marine and Freshwater Research*, *48*, 97–111.

Collins, B. D., Montgomery, D. R., Fetherston, K. L., & Abbe, T. B. (2012). The floodplain large-wood cycle hypothesis: A mechanism for the physical and biotic structuring of temperate forested alluvial valleys in the North Pacific coastal ecoregion. *Geomorphology*, *139–140*, 460–470.

Comiti, F., Lucia, A., & Rickenmann, D. (2016). Large wood recruitment and transport during large floods: A review. *Geomorphology*, *269*, 23–39.

Conley, W., & Kramer, N. (2020). Riverine large wood and recreation safety: A framework to discretize and contextualize hazard. *Earth Surface Processes and Landforms*, *45*, 2201–2216.

Constantine, J. A., Dunne, T., Ahmed, J., Legleiter, C., & Lazarus, E. D. (2014). Sediment supply as a drive of river meandering and floodplain evolution in the Amazon Basin. *Nature Geoscience*, *7*, 899–903.

Coulson, S. J., Hodkinson, I. D., Webb, N. R., & Harrison, J. A. (2002). Survival of terrestrial soil-dwelling arthropods on and in seawater: Implications for trans-ocean dispersal. *Functional Ecology*, *16*, 353–356.

Curran, J. C. (2010). Mobility of large woody debris (LWD) jams in a low gradient channel. *Geomorphology*, *116*, 320–329.

Curran, J. H., & Wohl, E. E. (2003). Large woody debris and flow resistance in step-pool channels, Cascade Range, Washington. *Geomorphology*, *51*, 141–157.

Czarnecka, M. (2016). Coarse woody debris in temperate littoral zones: Implications for biodiversity, food webs and lake management. *Hydrobiologia*, *767*, 13–25.

Daniels, M. D., & Rhoads, B. (2004). Effect of large woody debris configuration on three-dimensional flow structure in two low-energy meander bends at varying stages. *Water Resources Research*, *40*, W11302.

De Cicco, P. N., Paris, E., Ruiz-Villanueva, V., Solari, L., & Stoffel, M. (2018). In-channel wood-related hazards at bridges: A review. *River Research and Applications*, *34*, 617–628.

Deer Creek. (2022). The story of deer creek. Online story map. https://usfs.maps.arcgis.com/apps/Cascade/index.html?appid=a1eab14df971439580ac2c17e308fa09

Distel, D. L., Baco, A. R., Chuang, E., Morrill, W., Cavanaugh, C., & Smith, C. R. (2000). Do mussels take wooden steps to deep-sea vents?. *Nature*, *403*, 725–726.

Doong, D. J., Chuang, H. C., Shieh, C. L., & Hu, J. H. (2011). Quantity, distribution, and impacts of coastal driftwood triggered by a typhoon. *Marine Pollution Bulletin*, *62*, 1446–1454.

Doughty, M., Sawyer, A. H., Wohl, E., & Singha, K. (2020). Mapping increases in hyporheic exchange from channel-spanning logjams. *Journal of Hydrology*, *587*, 124931.

Dugan, J. E., & Hubbard, D. M. (2010). Loss of coastal strand habitat in southern California: The role of beach grooming. *Estuaries and Coasts*, *33*, 67–77.

Eamer, B. R., & Walker, I. J. (2010). Quantifying sand storage capacity of large woody debris on beaches using LiDAR. *Geomorphology*, *118*, 33–47.

Elmqvist, T., Folke, C., Nystrom, M., Peterson, G., Bengtsson, J., Walker, B., & Norberg, J. (2003). Response diversity, ecosystem change, and resilience. *Frontiers in Ecology and the Environment*, *9*, 488–494.

Fagervold, S. K., Galand, P. E., Zbinden, M., Gaill, F., Lebaron, P., & Palacios, C. (2012). Sunken woods on the ocean floor provide diverse specialized habitats for microorganisms. *FEMS Microbiology Ecology*, *82*, 616–628.

Florsheim, J. L., Mount, J. F., & Chin, A. (2008). Bank erosion as a desirable attribute of rivers. *Bioscience*, *58*, 519–529.

Francis, R. A., Tibaldeschi, P., & McDougall, L. (2008). Fluvially-deposited large wood and riparian plant diversity. *Wetlands Ecology and Management*, *16*, 371–382.

Freschet, G. T., Weedon, J. T., Aerts, R., Van Hal, J. R., & Cornelissen, J. H. C. (2012). Interspecific differences in wood decay rates: Insights from a new short-term method to study long-term wood decomposition. *Journal of Ecology*, *100*, 161–170.

Furlan, P., Pfister, M., Matos, J., & Schleiss, A. J. (2018). Spillway blockage caused by large wood in reservoirs. *River Flow*, *2018*(40), 02037.

Gerten, D., Hoff, H., Rockström, J., Jagermeyr, J., Kummu, M., & Pastor, A. V. (2013). Towards a revised planetary boundary for consumptive freshwater use: Role of environmental flow requirement. *Current Opinion in Environmental Sustainability*, *5*, 551–558.

Gheskiere, T., Vincx, M., Weslawski, J. M., Scapini, F., & Degraer, S. (2005). Meiofauana as descriptor of tourism-induced changes at sandy beaches. *Marine Environmental Research*, *60*, 245–265.

Gooding, R. M., & Magnuson, J. J. (1967). Ecological significance of a drifting object to pelagic fishes. *Pacific Science*, *21*, 486–497.

Goodman, A. C., Segura, C., Jones, J. A., & Swanson, F. J. (in press). Seventy years of watershed response to floods and changing forestry practices. *Earth Surface Processes and Landforms*. https://doi.org/10.1002/esp.5537

Grabowski, R. C., Gurnell, A. M., Burgess-Gamble, L., England, J., Holland, D., Klaar, M. J., … Wharton, G. (2019). The current state of the use of large wood in river restoration and management. *Water and Environment Journal*, *33*, 366–377.

Gracia, A., Rangel-Buitrago, N., & Florez, P. (2018). Beach litter and woody-debris colonizers on the Atlantico department Caribbean coastline, Colombia. *Marine Pollution Bulletin*, *128*, 185–196.

Gregory, S. V., Boyer, K. L., & Gurnell, A. M. (Eds.). (2003). *The ecology and Management of Wood in world Rivers*. Bethesda, MD: American Fisheries Society.

Gurnell, A. M. (2007). Analogies between mineral sediment and vegetative particle dynamics in fluvial systems. *Geomorphology*, *89*, 9–22.

Gurnell, A. M., Piegay, H., Swanson, F. J., & Gregory, S. V. (2002). Large wood and fluvial processes. *Freshwater Biology*, *47*, 601–619.

Gurnell, A. M., Tockner, K., Edwards, P., & Petts, G. (2005). Effects of deposited wood on biocomplexity of river corridors. *Frontiers in Ecology and the Environment*, *3*, 377–382.

Haden, G. A., Blinn, D. W., Shannon, J. P., & Wilson, K. P. (1999). Driftwood: An alternative habitat for macroinvertebrates in a large desert river. *Hydrobiologia*, *397*, 179–186.

Haga, H., Kumagai, T., Otsuki, K., & Ogawa, S. (2002). Transport and retention of coarse woody debris in mountain streams: An in situ field experiment of log transport and a field survey of coarse woody debris distribution. *Water Resources Research*, *38*, 1126–1-16.

Harmon, M. E., Franklin, J. F., Swanson, F. J., Sollins, P., Gregory, S. V., Lattin, J. D., … Cummins, K. W. (1986). Ecology of coarse woody debris in temperate ecosystems. *Advances in Ecological Research*, *15*, 133–302.

Heathfield, D. K., & Walker, I. J. (2011). Analysis of coastal dune dynamics, shoreline position, and large woody debris at Wickaninnish Bay, Pacific Rim National Park, British Columbia. *Canadian Journal of Earth Sciences*, *48*, 1185–1198.

Hester, E. T., & Doyle, M. W. (2008). In-stream geomorphic structures as drivers of hyporheic exchange. *Water Resources Research*, *44*, W03417.

Hinshaw, S., Wohl, E., Burnett, J. D., & Wondzell, S. (2022). Development of a geomorphic monitoring strategy for Stage 0 restoration in the South Fork McKenzie River, Oregon, USA. *Earth Surface Processes and Landforms*, *47*, 1937–1951.

Hood, W. G. (2007). Large woody debris influences vegetation zonation in an oligohaline tidal marsh. *Estuaries and Coasts*, *30*, 441–450.

Jeffries, R., Darby, S. E., Sear, D. A., Keller, E. A., & Swanson, J. J. (2003). The influence of vegetation and organic debris on flood-plain sediment dynamics: Case study of a low-order stream in the New Forest, England. *Geomorphology*, *51*, 61–80.

Johnson, E. R., Inamdar, S., Kan, J., & Vargas, R. (2018). Particulate organic matter composition in stream runoff following large storms: Role of POM sources, particle size, and event characteristics. *Journal of Geophysical Research Biogeosciences*, *123*, 660–675.

Johnson, L. B., Breneman, D. H., & Richards, C. (2003). Macroinvertebrate community structure and function associated with large wood in low gradient streams. *River Research and Applications*, *19*, 199–218.

Johnson, S. L., Swanson, F. J., Grant, G. E., & Wondzell, S. M. (2000). Riparian forest disturbances by a mountain flood – The influence of floated wood. *Hydrological Processes*, *14*, 3031–3050.

Kano, Y., Fukumori, H., Brenzinger, B., & Waren, A. (2013). Driftwood as a vector for the oceanic dispersal of estuarine gastropods (Neritidae) and an evolutionary pathway to the sunken-wood community. *Journal of Molluscan Studies*, *79*, 378–382.

Kemper, J. T., Thaxton, R. D., Rathburn, S. L., Friedman, J. M., Mueller, E. R., & Scott, M. L. (2022). Sediment-ecological connectivity in a large river network. *Earth Surface Processes and Landforms*, *47*, 639–657.

Kennedy, D. M., & Woods, J. L. D. (2012). The influence of coarse woody debris on gravel beach geomorphology. *Geomorphology*, *159–160*, 106–115. https://www.sciencedirect.com/science/article/pii/S0169555X12001274

Kleindl, W. J., Rains, M. C., Marshall, L. A., & Hauer, F. R. (2015). Fire and flood expand the floodplain shifting habitat mosaic concept. *Freshwater Science*, *34*, 1366–1382.

Kondolf, G. M., Gao, Y., Annandale, G. W., Morris, G. L., Jiang, E., Zhang, J., … Yang, C. T. (2014). Sustainable sediment management in reservoirs and regulated rivers: Experiences from five continents. *Earth's Future*, *2*, 256–280.

Kramer, N., & Wohl, E. (2014). Estimating fluvial wood discharge using time-lapse photography with varying sampling intervals. *Earth Surface Processes and Landforms*, *39*, 844–852.

Kramer, N., & Wohl, E. (2015). Drift cretions: The legacy impacts of driftwood on shoreline morphology. *Geophysical Research Letters*, *42*, 5855–5864.

Kramer, N., & Wohl, E. (2017). Rules of the road: A qualitative and quantitative synthesis of large wood transport through drainage networks. *Geomorphology*, *279*, 74–97.

Kramer, N., Wohl, E., Hess-Homeier, B., & Leisz, S. (2017). The pulse of driftwood export from a very large forested river basin over multiple time scales, Slave River, Canada. *Water Resources Research*, *53*, 1928–1947.

Krauss, K. W., Doyle, T. W., Twilley, R. R., Smith, T. J., Whelan, K. R., & Sullivan, J. K. (2005). Woody debris in the mangrove forests of South Florida. *Biotropica*, *37*, 9–15.

Lassettre, N. S., Piegay, H., Dufour, S., & Rollet, A.-J. (2008). Decadal changes in distribution and frequency of wood in a free meandering river, the Ain River, France. *Earth Surface Processes and Landforms*, *33*, 1098–1112.

Lininger, K. B., & Hilton, S. (2022). Large wood in small channels: A 20-year study of budgets and piece mobility in two redwood streams. *Water Resources Research*, *58*, e2022WR033047.

Livers, B., Lininger, K. B., Kramer, N., & Sendrowski, A. (2020). Porosity problems: Comparing and reviewing methods for estimating porosity and volume of wood jams in the field. *Earth Surface Processes and Landforms*, *45*, 3336–3353.

Livers, B., & Wohl, E. (2021). All logjams are not created equal. *Journal of Geophysical Research Earth Surface*, *126*, e2021JF006076.

Livers, B., Wohl, E., Jackson, K. J., & Sutfin, N. A. (2018). Historical land use as a driver of alternative states for stream form and function in forested mountain watersheds of the Southern Rocky Mountains. *Earth Surface Processes and Landforms*, *43*, 669–684.

MacVicar, B., & Piégay, H. (2012). Implementation and validation of video monitoring for wood budgeting in a wandering piedmont river, the Ain River (France). *Earth Surface Processes and Landforms*, *37*, 1272–1289.

MacVicar, B. J., Piegay, H., Henderson, A., Comiti, F., Oberlin, C., & Pecorari, E. (2009). Quantifying the temporal dynamics of wood in large rivers: Field trials of wood surveying, dating, tracking, and monitoring techniques. *Earth Surface Processes and Landforms*, *34*, 2031–2046.

Maggliozi, C., Usseglio-Polatera, P., Meyer, A., & Grabowski, R. C. (2019). Functional traits of hyporheic and benthic invertebrates reveal importance of wood-driven geomorphological processes in rivers. *Functional Ecology*, *33*, 1758–1770.

Manners, R. B., & Doyle, M. W. (2008). A mechanistic model of woody debris jam evolution and its application to wood-based restoration and management. *River Research and Applications*, *24*, 1104–1123.

Manners, R. B., Doyle, M. W., & Small, M. J. (2007). Structure and hydraulics of natural woody debris jams. *Water Resources Research*, *43*, W06432.

Marburg, A. E., Turner, M. G., & Kratz, T. K. (2006). Natural and anthropogenic variation in coarse wood among and within lakes. *Journal of Ecology*, *94*, 558–568.

McKenzie, M., Mathers, K. L., Wood, P. J., England, J., Foster, I., Lawler, D., & Wilkes, M. (2020). Potential physical effects of suspended fine sediment on lotic macroinvertebrates. *Hydrobiologia*, *847*, 697–711.

McLeod, R. J., & Wing, S. R. (2007). Hagfish in the New Zealand fjords are supported by chemoautotrophy of forest carbon. *Ecology*, *88*, 809–816.

Merten, E. C., Vaz, P. G., Decker-Fritz, J. A., Finlay, J. C., & Stefan, H. G. (2013). Relative importance of breakage and decay as processes depleting large wood from streams. *Geomorphology*, *190*, 40–47.

Montgomery, D. R., & Abbe, T. B. (2006). Influence of logjam-formed hard points on the formation of valley-bottom landforms in an old-growth forest valley, Queets River, Washington, USA. *Quaternary Research*, *65*, 147–155.

Mörtl, C., & De Cesare, G. (2021). Sediment augmentation for river rehabilitation and management – A review. *Land*, *10*, 1309.

Naiman, R. J., Bechtold, J. S., Beechie, T. J., Latterell, J. J., & Van Pelt, R. (2010). A process-based view of floodplain forest patterns in coastal river valleys of the Pacific Northwest. *Ecosystems*, *13*, 1–31.

Nakamura, F., Shin, N., & Inahara, S. (2007). Shifting mosaic in maintaining diversity of floodplain tree species in the northern temperate zone of Japan. *Forest Ecology and Management*, *241*, 28–38.

O'Connor, N. A. (1992). Quantification of submerged wood in a lowland Australian system. *Freshwater Biology*, *27*, 387–395.

Osei, N. A., Gurnell, A. M., & Harvey, G. L. (2015). The role of large wood in retaining fine sediment, organic matter and plant propagules in a small, single-thread forest river. *Geomorphology*, *235*, 77–87.

Panici, D., Kripakaran, P., Djordjevic, S., & Dentith, K. (2020). A practical method to assess risks from large wood debris accumulations at bridge piers. *Science of the Total Environment*, *728*, 138575.

Pellegrini, G., Martini, L., Rainato, R., & Picco, L. (2022). Large wood mobilization and morphological changes in an alpine river following the release of an ordinary experimental flood from an upstream dam. *Catena*, *216*, 106398.

Persi, E., Petaccia, G., Sibilla, S., Lucia, A., Andreoli, A., & Comiti, F. (2020). Numerical modelling of uncongested wood transport in the Rienz River. *Environmental Fluid Mechanics*, *20*, 539–558.

Pettit, N. E., Latterell, J. J., & Naiman, R. J. (2006). Formation, distribution and ecological consequences of flood-related wood debris piles in a bedrock confined river in semi-arid South Africa. *River Research and Applications*, *22*, 1097–1100.

Pettit, N. E., Naiman, R. J., Rogers, K. H., & Little, J. E. (2005). Post-flooding distribution and characteristics of large woody debris piles along the semi-arid Sabie River, South Africa. *River Research and Applications*, *21*, 27–38.

Phillips, J. D. (2003). Sources of nonlinear and geomorphic complexity in geomorphic systems. *Progress in Physical Geography*, *27*, 1–23.

Pilotto, F., Harvey, G. L., Wharton, G., & Pusch, M. T. (2016). Simple large wood structures promote hydromorphological heterogeneity and benthic macroinvertebrate diversity in low-gradient rivers. *Aquatic Sciences*, *78*, 755–766.

Poff, N. L., Allan, J. D., Bain, M. B., Karr, J. R., Prestegaard, K. L., Richter, B. D., … Stromberg, J. C. (1997). The natural flow regime. *Bioscience*, *47*, 769–784.

Pringle, C. M., Naiman, R. J., Bretschko, G., Karr, J. R., Oswood, M. W., Webster, J. R., … Winterbourn, M. J. (1988). Patch dynamics in lotic systems: The stream as a mosaic. *Freshwater Science*, *7*, 503–524.

Ravvazolo, D., Mao, L., Picco, L., & Lenzi, M. A. (2015). Tracking log displacement during floods in the Tagliamento River using RFID and GPS tracker devices. *Geomorphology*, *228*, 226–233.

Richmond, A. D., & Fausch, K. D. (1995). Characteristics and function of large woody debris in subalpine Rocky Mountain streams in northern Colorado. *Canadian Journal of Fisheries and Aquatic Sciences*, *52*, 1789–1802.

Roni, P., Beechie, T., Pess, G., & Hanson, K. (2015). Wood placement in river restoration: Fact, fiction, and future direction. *Canadian Journal of Fisheries and Aquatic Sciences*, *72*, 466–478.

Ruiz-Villanueva, V., Blade, E., Sanchez-Juny, M., Marti-Cardona, B., Diez-Herrero, A., & Bodoque, J. M. (2014). Two-dimensional numerical modeling of wood transport. *Journal of Hydroinformatics*, *16*, 1077–1096.

Ruiz-Villanueva, V., Mazzorana, B., Blade, E., Burkli, L., Iribarren-Anacona, P., Mao, L., … Wohl, E. (2019). Characterization of wood-laden flows in rivers. *Earth Surface Processes and Landforms*, *44*, 1694–1709.

Ruiz-Villanueva, V., Piegay, H., Gurnell, A. M., Marston, R. A., & Stoffel, M. (2016). Recent advances quantifying the large wood dynamics in river basins: New methods and remaining challenges. *Reviews of Geophysics*, *54*, 611–652.

Schalko, I., Schmocker, L., Weitbrecht, V., & Boes, R. M. (2020a). Laboratory study on wood accumulation probability at bridge piers. *Journal of Hydraulic Research*, *58*, 566–581.

Schalko, I., Schmocker, L., Weitbrecht, V., & Boes, R. M. (2020b). Risk reduction measures of large wood accumulations at bridges. *Environmental Fluid Mechanics*, *20*, 485–502.

Schenk, E. R., Moulin, B., Hupp, C. R., & Richter, J. M. (2014). Large wood budget and transport dynamics on a large river using radio telemetry. *Earth Surface Processes and Landforms*, *39*, 487–498.

Shields, F. D., & Smith, R. H. (1992). Effects of large woody debris removal on physical characteristics of a sand-bed river. *Aquatic Conservation Marine and Freshwater Ecosystems*, *2*, 145–163.

Stanford, J. A., Lorang, M. S., & Hauer, F. R. (2005). The shifting habitat mosaic of river ecosystems. *Verhandlungen Internationale Vereinigung Limnologie*, *29*, 123–126.

Storry, K. A., Weldrick, C. K., Mews, M., Zimmer, M., & Jelinski, D. E. (2006). Intertidal coarse woody debris: A spatial subsidy as shelter or feeding habitat for gastropods? *Estuarine and Coastal Shelf Science*, *66*, 197–203.

Swanson, F. J., Gregory, S. V., Iroume, A., Ruiz-Villanueva, V., & Wohl, E. (2021). Reflections on the history of research on large wood in rivers. *Earth Surface Processes and Landforms*, *46*, 55–66.

Tank, J. L., Rosi-Marshall, E. J., Griffiths, N. A., Entrekin, S. A., & Stephen, M. L. (2010). A review of allochthonous organic matter dynamics and metabolism in streams. *Journal North American Benthological Society*, *29*, 118–146.

Tharme, R. E. (2003). A global perspective on environmental flow assessment: Emerging trends in the development and application of environmental flow methodologies for rivers. *River Research and Applications*, *19*, 397–441.

Thiel, M., & Gutow, L. (2004). The ecology of rafting in the marine environment. I. The floating substrata. *Oceanography and Marine Biology: An Annual Review*, *42*, 181–264.

Trakhtenbrot, A., Nathan, R., Perry, G., & Richardson, D. M. (2005). The importance of long-distance dispersal in biodiversity conservation. *Diversity and Distributions*, *11*, 173–181.

Umazano, A. M., & Melchor, R. N. (2020). Volcaniclastic sedimentation influenced by logjam breakups? An example from the Blanco River, Chile. *Journal of South American Earth Sciences*, *98*, 102477.

Wallace, J. B., & Benke, A. C. (1984). Quantification of wood habitat in subtropical coastal plain streams. *Canadian Journal of Fisheries and Aquatic Sciences*, *41*, 1643–1652.

Ward, G. M., & Aumen, N. G. (1986). Woody debris as a source of fine particulate organic matter in coniferous forest stream ecosystems. *Canadian Journal of Fisheries and Aquatic Sciences*, *43*, 1635–1642.

Weedon, J. T., Cornwell, W. K., Cornelissen, J. H. C., Zanne, A. E., Wirth, C., & Coomes, D. A. (2009). Global meta-analysis of wood decomposition rates: A role for trait variation among tree species? *Ecology Letters*, *12*, 45–56.

Wildish, D. J. (2012). Long distance dispersal and evolution of talitrids (Crustacea: Amphipoda: Talitridae) in the Northeast Atlantic islands. *Journal of Natural History*, *46*, 2329–2348.

Wohl, E. (2011). Threshold-induced complex behavior of wood in mountain streams. *Geology*, *39*, 587–590.

Wohl, E. (2017). Bridging the gaps: An overview of wood across time and space in diverse rivers. *Geomorphology*, *279*, 3–26.

Wohl, E. (2020). Wood process domains and wood loads on floodplains. *Earth Surface Processes and Landforms*, *45*, 144–156.

Wohl, E., Bledsoe, B. P., Jacobson, R. B., Poff, N. L., Rathburn, S. L., Walters, D. M., & Wilcox, A. C. (2015). The natural sediment regime in rivers: Broadening the foundation for ecosystem management. *Bioscience*, *65*, 358–371.

Wohl, E., & Goode, J. R. (2008). Wood dynamics in headwater streams of the Colorado Rocky Mountains. *Water Resources Research*, *44*, W09429.

Wohl, E., & Iskin, E. P. (2021). Damming the wood falls. *Science Advances*, *7*, eabj0988.

Wohl, E., & Iskin, E. P. (2022). The transience of channel-spanning logjams in mountain streams. *Water Resources Research*, *58*, e2021WR031556.

Wohl, E., Kramer, N., Ruiz-Villanueva, V., Scott, D. N., Comiti, F., Gurnell, A. M., … Fausch, K. D. (2019). The natural wood regime in rivers. *Bioscience*, *69*, 259–273.

Wohl, E., Marshall, A. E., Scamardo, J., White, D., & Morrison, R. R. (2022). Biogeomorphic influences on river corridor resilience to wildfire disturbances in a mountain stream of the Southern Rockies, USA. *Science of the Total Environment*, *820*, 153321.

Wohl, E., & Scamardo, J. E. (2021). The resilience of logjams to floods. *Hydrological Processes*, *35*, e13970.

Wyżga, B., & Zawiejska, J. (2005). Wood storage in a wide mountain river: Case study of the Czarny Dunajec, Polish Carpathians. *Earth Surface Processes and Landforms*, *30*, 1475–1494.

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