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Editorial

Wood in rivers: interactions with channel morphology and processes

No doubt about it, wood complicates fluvial geomorphology. It messes up nice tidy streams, complicates quantitative analysis, invalidates convenient assumptions, and opens new questions about how different contemporary channels are from their pristine state. It is no coincidence that modern fluvial geomorphology developed through the study of channels lacking a substantial load of wood debris (Leopold et al., 1964) and there is little mystery as to why geomorphologists sought to study rivers or river reaches where wood does not exert a significant influence on channel morphology and processes. However, over the past several decades, recognition has grown that wood debris significantly and sometimes systematically affects channel processes in forested regions across a wide range of scales from channel roughness and bed-surface grain size (Lisle, 1995; Shields and Gippel, 1995; Buffington and Montgomery, 1999; Manga and Kirchner, 2000); to creation of in-channel features, such as pools and steps (Keller and Tally, 1979; Nakamura and Swanson, 1993; Lisle, 1995; Montgomery et al., 1995, 1996); even to large-scale controls on channel pattern (e.g., channel shifting and cut-off; Keller and Swanson, 1979; Hickin, 1984; Piégay, 1993; Piégay and Marston, 1998) and the formation of flood plains and valley-bottom landforms (Abbe and Montgomery, 1996; Piégay and Gurnell, 1997; Piégay et al., 1998; Gurnell et al., 2001).

Modern forests cover almost a third of Earth's land surface, and wood debris has been entering streams and rivers for more than 400 million years. There is little doubt that vegetation influenced ancient rivers; the first appearance of meandering stream deposits in the geologic record coincides with the evolution of land plants (Schumm, 1968; Cotter, 1978). In the less remote past, late Cenozoic changes in global vegetation patterns imparted substantial variability to the role of wood in world rivers. Whereas only a few European rivers in small isolated areas of forest refugia would have had significant wood loading during the glacial maxima, parts of eastern Australia have been continuously forested for more than 100 million years. In historic times, humans have reduced global forest cover to about half its maximum Holocene extent and eliminated all but a fraction of the world's aboriginal forests. Although the net effects of human actions have been to homogenize and simplify river systems around the world, there are still strong regional contrasts in the geomorphological effects of wood in rivers.

In most industrialized nations, the primeval character of rivers remains shrouded by time because of ancient deforestation and river clearing to improve navigation before recorded history. Human alteration of forests in Europe has been significant for at least 6000 years (Williams, 2000). Forests in southern Europe were already confined to mountainous areas by classical times (Darby, 1956), and river clearing and engineering date to the Roman era (Herget, 2000). The morphology of the riparian trees established along European stream channels reflects centuries of successive clearing campaigns, tree selection favoring root network growth, and efforts to prevent bank erosion. As the geomorphic effects of centuries of "riparian gardening" are revealed by progress in the understanding of both structural effects of LWD on channel forms and the natural geometry of stream channels in rural areas, the full extent of human-induced aspects of stream geometry is becoming more and more evident in European rivers.

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Although European forests were cleared over millennia, the vast forests of North America vanished much more rapidly, with forest stands near rivers usually the first to be logged. By the late 19th century, efforts to clear wood from rivers extended throughout the US to reach the west coast (Sedell and Frogatt, 1984; Collins et al., 2002). While large rivers were being cleaned of snags and jams, smaller tributary streams were cleared through practices such as splash damming, salvage of in-stream wood, or stream cleaning (Triska, 1984). Few examples of undisturbed river systems remain in the continental United States or in Australia, and those that do are quite remote and difficult to access. Although the role of wood debris has been studied in some relatively undisturbed forest streams, most research on wood in channels is from small streams.

Interest in the geomorphic effects of wood in rivers has increased since the 1970s in the US because of historical works that described campaigns of LWD removal to improve navigation. Accounts of the effects of huge log jams were common in early descriptions of North American rivers. Even in early editions of his famous text, Charles Lyell commented on the geological significance of vast accumulations of logs in American rivers (Lyell, 1837). Ever since Lyell's time, there has been a perception that wood is less important in European rivers than in North American rivers—and those in the Pacific Northwest in particular. However, the extent to which such perceptions primarily attest to a legacy of ancient deforestation and river clearing is only now being addressed. Pioneering works that revealed the strong linkages between LWD and fish abundance and diversity have been instrumental in demonstrating the ecological roles of wood in channels and stream ecosystems. Such studies helped to refute the once popular idea that a clean river, which may be good for humans, is also good for fish, particularly salmon. A similar evolution in thought has occurred in Australia since the work of Gippel et al. (1994). A large part of the research developed in the US on LWD has been motivated by linkages between fish habitat and geomorphological processes and forms influenced by LWD.

The trend observed in Europe is slightly different because of the particular environmental context and the difficulty in recognizing the role of LWD in temperate fluvial systems due to millennia of channel gardening and the near total absence of historical documents demonstrating the abundance of wood in pristine European rivers and streams. Nevertheless, interest in the study of LWD in European streams is increasing because of American literature describing temperate river landscapes before European settlement and also because of major land use changes in rural areas. Since the end of the 19th century, and mainly after the Second World War, the old continent has been characterized by an agricultural revolution; and a large part of the mountain areas (such as the Alps, the Apennines, or the Pyrenees) underwent major afforestation and rural depopulation, leading to an increase of LWD in streams and rivers because of progressive abandonment of vegetation maintenance practices and natural senescence of riparian trees. Natural recovery of channel forms and processes with LWD input is beginning to be observed in riparian zones where afforestation began 50 years ago (Boyer et al., 1998). As it re-enters European river systems, LWD is becoming a research topic of increasing interest in France, Germany, Poland, Spain, Sweden, and the UK.

Wood produces or catalyzes both direct and indirect geomorphological effects on rivers across a wide range of scales. Depending on the size of a log and the size of the channel it fell into, a log may remain stable at or near where it fell; or it may move downstream to lodge against the bank or in a log jam, become stranded during falling flow, lodge in the riverbed as a snag, or float out of the basin. Many of the geomorphic effects of wood in rivers arise from the influence of stable wood debris that acts as an obstruction to local flow hydraulics and sediment transport and the material that it collects, which further contribute to reinforce a flow obstruction.

In channels with a substantial load of wood debris, local influences on flow and sediment transport can generate emergent properties at larger scales of channel reaches and valley bottoms. It is simple to observe how wood debris can dramatically affect the size and type of pools, bars, steps, and other local features such as channel width (Lisle, 1986; Keller et al., 1995; Montgomery et al., 1995; Woodsmith and Buffington, 1996; Hogan et al., 1998). At the scale of channel reaches, wood debris has a strong control on the frequency of pools and bars and can create significant hydraulic roughness, influencing flow velocity, discharge, shear stress, bed load transport rates, and reach-average surface grain sizes (MacDonald and Keller, 1987; Smith et al., 1993; Assani and Petit, 1995; Shields and Gippel, 1995; Buffington and Montgomery, 1999; Manga and Kirchner, 2000). The effect of wood debris on channel hydraulics and sediment transport provides a strong control on reach-scale channel morphology (Keller and Swanson, 1979; Heede, 1981; Marston, 1982; Swanson et al., 1976; Montgomery et al., 1995, 1996) and can have a profound influence on the availability and diversity of aquatic habitats in forest channels (Wallace and Benke, 1984; Harmon et al., 1986; Bilby and Bisson, 1998).

Even accounting for historic (and prehistoric) changes in the amount of wood in rivers, the importance of wood varies in different river systems (Gurnell et al., 2002). Regional differences in the geomorphological effects of wood in rivers reflect differences in wood size, density, and shape that are partly controlled by wood availability, depending on external factors controlling wood recruitment and the character of the surrounding forest as well as in river size, characteristics, and processes. Widely spreading or multiple-stemmed hardwoods are more prone to forming snags than accumulating as racked members in large log jams because they extend laterally to well beyond their bole diameter. In contrast, coniferous wood debris tends to be cylindrical pieces more readily transported and routed through river systems, resulting in local concentrations or log jams along the river system. Nevertheless, we can expect to find in-channel wood in large rivers draining not only forested mountain catchments but also desert areas (Minkley and Rinne, 1985) or lowland regions (Triska, 1984). The question of whether LWD is stable and influences channel forms and processes involves both the relative size of key wood elements compared to channel size and the sensitivity of channel form itself to changes imposed by stable flow obstructions.

A key geomorphological challenge is to better understand how wood influenced pristine temperate rivers, as well as how it controls the hydraulics and geomorphological features (and their life spans) in channels of various size in different regional environments. Are there any important differences in the effects of LWD either on fluvial forms and processes between lowland and montane rivers and streams or between tropical and temperate systems? These questions remain but partially addressed. Fundamental knowledge of the geomorphological effects of wood on channel morphology and processes is still needed in order to better manage the impacts of human actions on LWD recruitment and stability (Downs and Simon, 2001), evaluation of flood risk and potential damage to infrastructure (Diehl, 1997), and reintroducing wood in habitat rehabilitation programs to enhance aquatic ecosystems (Gurnell et al., 1995).

As is appropriate for such a broad subject, the papers in this volume explore the geomorphological effects of wood in rivers across a wide range of scales and landscapes. This issue begins with two papers focused on a long-term perspective emphasizing the strong effect of woody debris on valley-bottom landforms in Australia (Brooks et al.) and the Olympic Peninsula, Washington (O'Connor et al.). At shorter time and spatial scales, Jeffries et al. describe the effect of woody debris stored in the channel on the flood plain features and flood plain sedimentation pattern. The volume then focuses on spatial and structural complexity of wood accumulations. From a detailed reconnaissance of the Queets River network in the Olympic Peninsula, Washington, Abbe and Montgomery (1996) propose a process-based typology of wood accumulations based on their stability and morphological effects and discuss their longitudinal distribution along the river system. The characteristics of wood accumulations (e.g., residence time, geographical origin, density, and spatial pattern) are then studied at the shorter spatial scale of a 700-m-long reach of the Tonghi Creek, Australia, an undisturbed, lowland stream (Webb and Erskine). The question of how to characterize the spatial organization of in-stream wood is also introduced from a methodological point of view by Kraft and Warren, who performed a geostatistical analysis for assessing the longitudinal organization of wood accumulations.

The volume then progresses to studies of how LWD influences active channel processes. Papers on the influence of wood on channel hydraulics explore the mechanisms behind the geomorphological influences of wood in natural environments such as step-pool channels (Curran and Wohl) or in meander bends (Daniels and Rhoads), and also using model debris (Hygelund and Manga). Three final papers illustrate similarities and contrasts in the influence of wood on channel processes and morphology (Faustini and Jones; Gomi et al.; Kail). The first two concern headwater streams of the American Pacific Northwest, whereas the third focuses on central European streams draining lowlands and low-elevation mountains.

Notably absent from this volume is work on tropical rivers where rapid decay and different types of wood may strongly affect the influence of wood on rivers, flume experiments to improve our understanding of wood mobility and long-term effects on fluvial forms, and also experiences in the use of wood in river restoration. These omissions only reinforce how the variety of approaches and contexts of these papers illustrate the broad scope of the study of the geomorphological effects of wood in rivers. Moreover, this collection of papers emphasizes that a common challenge in North America, Australia and Europe is to understand how the manner in which LWD structures channel forms and processes, habitat complexity, and valley-bottom landforms can be used to better inform both river management and restoration efforts.

Wood debris is a major geomorphic agent in forested regions, and models of fluvial geomorphology need to account for its influence in spite of the challenges this presents. The size and shape of trees and the characteristics of their wood vary regionally and longitudinally through a fluvial system, and these variations impart global patterns to the geomorphic influence of wood debris. The potential for even relatively large rivers to be influenced by log jams emphasizes the need to incorporate the effects of wood debris into geomorphic models and thinking across all scales in forest river systems. The time has arrived for wood, and vegetation in general, to assume a place beside the sediment regime (e.g., sediment supply and sediment caliber) and the discharge regime as a primary control on the morphology and dynamics of river systems.

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