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Frequency of large in-channel wood in eastern Oklahoma ecoregions and its association with channel morphology

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ABSTRACT

Regional climate, geology, vegetation, and land use influence hydrogeomorphic processes, which influence stream channel form and the recruitment and transport of wood in streams. We studied relationships between channel morphology and frequencies of large in-channel wood in three upland ecoregions of eastern Oklahoma where streams contain high fish diversity and valuable sport fisheries. We surveyed 138 streams for wood within the Boston Mountains ($n = 30$), Ozark Highlands ($n = 30$), and Ouachita Mountain ($n = 78$) ecoregions. Our study investigated whether (1) the frequency of large wood differed among ecoregions; (2) channel morphology influenced the distribution of large wood within and among ecoregions; and (3) a relationship existed between the frequency and size of trees in the riparian zone and the frequency of large wood within and among ecoregions. The frequency of single large wood pieces did not differ among ecoregions or vary with drainage area. However, the presence of one or more wood accumulation (2 to 4 pieces) increased with drainage area and increased at a higher rate in the Boston Mountains and Ozark Highlands than in the Ouachita Mountains. The frequency of single wood pieces decreased in narrower channels with larger substrates but increased in larger stream channels overall. No association existed between riparian tree density and in-channel wood in study reaches. We discuss these results in the context of wood recruitment and transport, and highlight key questions that remain regarding wood in eastern Oklahoma streams.

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1. Introduction

Hydrogeomorphic processes operate within the broad regional context of climate, geology, topography, and vegetation (Montgomery and Bolton, 2003). The processes of water, sediment, and wood transport in streams and rivers reflect this regional context (Knighton, 1998). Downstream transport processes, and the interaction of transported materials with local geology and streamside vegetation, play a large role in determining the morphologic and ecological characteristics of streams that influence habitat suitability for aquatic organisms (Montgomery, 1999). For this reason, ecoregions with similar geology, topography, land use, soils, and vegetation have served as a useful framework for the characterization and management of aquatic resources (Omernik, 1987; Carlisle et al., 2010; Splinter et al., 2010).

Regional context influences the recruitment and transport of wood in streams. Tree mortality from succession or disease or from disturbances such as fire, landslides, windstorms, and bank erosion are the predominant recruitment processes of wood in streams (Benda et al., 2003). The relative contribution of these processes, however, differ regionally depending on watershed characteristics, vegetation, disturbances, and streambank erosion rates that reflect channel morphology and stability and can influence local wood recruitment (Ruiz-Villanueva et al., 2014).

Once large wood enters the stream, it is stored or transported depending on wood buoyancy and impingement (Gurnell, 2003). The frequency and duration of medium-to-large floods determine wood transport rates (Ravazollo et al., 2015). Impingement rate is influenced by wood stem length relative to channel size, the presence of rootwads on stems, and the presence of channel features such as bars, islands, and deltas (Bertoldi et al., 2014). The influence of wood on local streambed scour and sediment sorting creates habitat used directly by fishes (Ayllón et al., 2009) and has been shown to influence their growth rates (Quist and Guy, 2001).

Large wood influences morphological changes at the reach scale, including the spacing of channel units, cross-sectional profile, channel slope, and sinuosity (Nakamura and Swanson, 1993; Montgomery et al., 1995; Faustini and Jones, 2003; Kail, 2003; Trimble, 2004). At the channel unit scale, large wood affects sediment routing and the size and type of channel units (Keller and Swanson, 1979; Marston, 1982; Andrus et al., 1988; Chin, 1989; Montgomery et al., 1995; Abbe

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and Montgomery, 1996; Wohl et al., 1997; Rosenfeld and Huato, 2003; Kreutzweiser et al., 2005). Understanding regional differences between channel morphology and large wood is important because wood can be used in stream habitat restoration and enhancement design that is often conducted at the reach scale (100–1000 m; Cordova et al., 2007; Roni et al., 2015).

Eastern Oklahoma contains high-value streams with fisheries of economic importance (Fisher et al., 2002; Martin and Fisher, 2008). Fisher et al. (2002) estimated that anglers spent ~24 million USD in 1993 on fishing trip expenditures in eastern Oklahoma streams and rivers, where several studies have shown linkages between wood and fishes. Dauwalter et al. (2008) showed that the composition of fish assemblages was influenced by wood densities in eastern Oklahoma streams. Other studies have shown linkages between smallmouth bass (*Micropterus dolomieu*), an important sport fish, and wood at smaller spatial scales in eastern Oklahoma streams. At the microhabitat scale, smallmouth bass build nests near large wood during spring spawning that may shelter nests during high streamflows (Lukas and Orth, 1995; Dauwalter and Fisher, 2007), and juvenile and adult smallmouth bass are likely to use wood as cover during nonbreeding seasons (Fore et al., 2007; Remshardt and Fisher, 2009). Smallmouth bass are also more abundant in deeper habitats (runs, pools) of larger eastern Oklahoma streams with wide, shallow channels (Dauwalter et al., 2007), which are more prevalent in the Ozark Highlands and Boston Mountains (as opposed to the southeastern Ouachita Mountains) because of different watershed morphology, lithology, vegetation, precipitation, and other ecoregion characteristics (Woods et al., 2005; Splinter et al., 2010, 2011; Splinter, 2013). Despite its importance to fishes, little is known about the distribution or frequency of large in-channel wood or its association with channel morphology in eastern Oklahoma streams.

The purpose of this paper is to examine the distribution of large in-channel wood in eastern Oklahoma streams within three upland ecoregions: Boston Mountains, Ozark Highlands, and Ouachita Mountains. In this paper we addressed the following questions: (i) does the frequency of large wood (single piece, accumulations, and jams) differ by drainage area and among ecoregions?; (ii) do reach-scale variables (particle size, sinuosity, gradient, width:depth ratio, bankfull width—variables that often reflect stream channel stability) influence the distribution of large wood?; and (iii) does a relationship exist between the frequency and size of trees in the riparian zone and the frequency of large wood?

2. Study area

The three ecoregions providing the spatial organization of this study are the Boston Mountains, Ozark Highlands, and the Ouachita Mountains (Omernik, 1987). A summary of their characteristics are presented in Table 1. The Oklahoma highland ecoregions of the Boston Mountains (1891 km^2) and Ozark Highlands (2795 km^2) are more similar to each other than the more rugged Ouachita Mountains (10,100 km^2; Woods et al., 2005). This is, in part, based on their underlying geology (Table 1). The Ouachita Mountains are characterized by intensely folded and faulted structures, whereas the Boston Mountains and Ozark Highlands show much less deformation of rock structure and form a cuestaform topography with plateau uplands (Thornbury, 1965). Additional similarities between the Boston Mountains and Ozark Highlands are that they are both highly dissected, covered by oak-hickory forest, have similar mean annual precipitation, and maintain many of the same fish species (Table 1; Woods et al., 2005; Dauwalter et al., 2008).

Distinct differences between the Boston Mountains and Ozark Highlands include lithology, soils, and land use. Although the Boston Mountains and Ozark Highlands have a similar topography, the Boston Mountains have a much higher relief than the Ozark Highlands (Table 1; Splinter et al., 2011). The lithology of the Boston Mountains is primarily sandstone and shale, whereas the Ozark Highlands are cherty limestone. Stream bank erosion, as a result of current and historical land use (logging and agriculture), in the Ozark Highlands has increased in-stream gravel, which has caused aggradation and a spatial and temporal fluctuation in pool habitat distribution (Woods et al., 2005; Splinter et al., 2010).

The Ouachita Mountains are south of the Boston Mountains and Ozark Highlands and separated by the Arkansas River valley. The Ouachita Mountains receive more precipitation, on average, than the Boston Mountains and Ozark Highlands (Table 1). In-stream sediment consists of gravel, cobble, boulder, or bedrock and tends to be larger than substrates in the Ozark Highlands or Boston Mountains (Woods et al., 2005; Splinter et al., 2010). In large pools, substrate in the Ouachita Mountains often consists of organic matter and fine-grained materials (Woods et al., 2005). Logging and recreation are two dominant land use practices. Vegetation consists of oak-hickory-shortleaf pine on uplands, with agriculture occurring in wider valleys (Woods et al., 2005).

The topography, geology, and precipitation differences among ecoregions lead to ecoregional differences in streamflows. Leasure et al. (2016) studied various streamflow metrics as a function of climate,

Table 1
Summary characteristics of highland ecoregions in eastern Oklahoma (description from Woods et al., 2005).

	Boston Mountains	Ozark Highlands	Ouachita Mountains
Geology			
Bedrock:	Pennsylvanian-aged sandstone and shale with minor amounts of Pennsylvanian and Mississippian-aged limestone	Mississippian-aged limestone and interbedded chert with Devonian-aged shale, dolostone, and limestone	Folded and faulted Pennsylvanian and Mississippian-aged sandstone, shale, and chert
Floodplain/low terrace soils			
Order:	Inceptisols, Mollisols	Entisols, Mollisols, Alfisols	Entisols, Alfisols
Series:	Rosebloom, Mason, Huntington, Ennis	Huntington, Sallisaw, Elsah, Staser	Ceda, Frizzell, Neff, Rexor, Dela, Kenn, Pushmataha
Climate			
Precipitation:	44–51 in.	41–49 in.	43–57 in.
Temperature:	January min/max (26/48 °F) July min/max (69/92 °F)	January min/max (22/48 °F) July min/max (69/91 °F)	January min/max (24/53 °F) July min/max (70/94 °F)
Vegetation			
Potential natural:	Mostly oak-hickory forest	Mostly oak-hickory forest and some oak-hickory-pine forest	Oak-hickory-pine forest
Floodplain:	Forests contain birch, sycamore, cottonwood, elms, and willow	Willow, maples, hickories, birch, American elm, and sycamore	Southern red oak, sweetgum, sycamore, white oak, pine, blackgum, water oak, willow oak, hickories, maples, eastern cottonwood
Land Use			
Dominant:	Pasture or hay, logging and recreation	Livestock and poultry/cattle farming, recreation	Pasture or hay, logging, recreation, woodland grazing