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Disturbance legacies of historic tie-drives persistently alter geomorphology and large wood characteristics in headwater streams, southeast Wyoming

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ABSTRACT

Instream wood is recognized as an integral component of stream morphology in forested areas. However, few studies have evaluated the legacy effects of historic wood removal activities and associated impacts on channel morphology, contemporary wood loading, and recruitment. This study investigates the role of historic tie-driving, a widespread channel disturbance legacy, in shaping present-day stream channel conditions in southern Wyoming. Geomorphic and riparian surveys were used to assess the extent of disturbance and degree of recovery within three sets of paired tie-driven and non-driven study reaches. Tie-driven streams were narrower, shallower, and had low cross-sectional roughness and higher width-to-depth ratios when compared to non-driven streams. Study reaches in first-order tie-driven streams were characterized by predominantly plane-bed morphologies and an extremely low abundance of wood compared to paired, non-driven reaches. Wood loads in second-order tie-driven reaches were similar to non-driven reaches, but overall wood distribution varied and was more likely to accumulate in jams. Existing wood loads in tie-driven reaches exhibited a narrower range of geomorphic functions and were less stable overall, although the relative state of decay was similar across all reaches. Basal area, stream power, and reach slope were identified as key mechanisms driving wood retention in the study reaches. The results of this study suggest that contemporary channel morphology and wood loads continue to reflect disturbance histories but have not yet been affected by other contemporary disturbances expected to influence wood loads such as bark beetle infestations.

1. Introduction

While billions of dollars have been invested in stream restoration in the United States, restoration efforts may not be producing the desired ecosystem improvements, indicating a disconnect between river science and river restoration practice (Bernhardt et al., 2005; Palmer, 2009). The reliance on reference reaches to provide a baseline or target condition for restoration projects compounds other shortcomings related to restoration techniques. Reference reaches, or minimally impaired systems that approximate characteristic stream function, are often used as templates to guide many restoration projects and management initiatives. Reference reaches are chosen based on a variety of considerations including their ability to represent pre-disturbance conditions (Brookes, 1987) as well as similarities in morphology (Rosgen, 1994), physiographic qualities (Montgomery et al., 1995), and more recently, analytical characteristics that capture process-based dynamics instead of form-based features (Downs and Simon, 2001). However, the selection of reference reaches requires an understanding of historic system conditions as well as future response trajectories. Given the spatial extent and history of human impacts on stream systems (Gregory, 2006), altered systems derived from past disturbance events (hereafter referred to as disturbance legacies) underlie much of our contemporary understanding of what constitutes *natural* stream function (Walter and Merritts, 2008; Burchsted et al., 2010; Downs and Simon, 2011).

One aspect of fluvial geomorphology that is often overlooked in the reference stream selection process is the role of large wood (LW). The scientific study of the functional role of LW in streams has a rich theoretical foundation in terms of channel form and of process-based implications for stream systems (e.g., Keller and Swanson, 1979; Lienkaemper and Swanson, 1987; Marston et al., 1995; Brooks and Brierley, 2002; Flores et al., 2011). The geomorphic impacts of LW are numerous and include the alteration of flow patterns (Gippel, 1995; Daniels and Rhoads, 2004), storage of organic matter and sediment (Lisle, 1995; Thompson, 1995; Montgomery et al., 2003; Daniels, 2006), and controls on bedform morphology (Montgomery et al., 1995). Considerable effort has focused on recruitment mechanisms and patterns (Downs and

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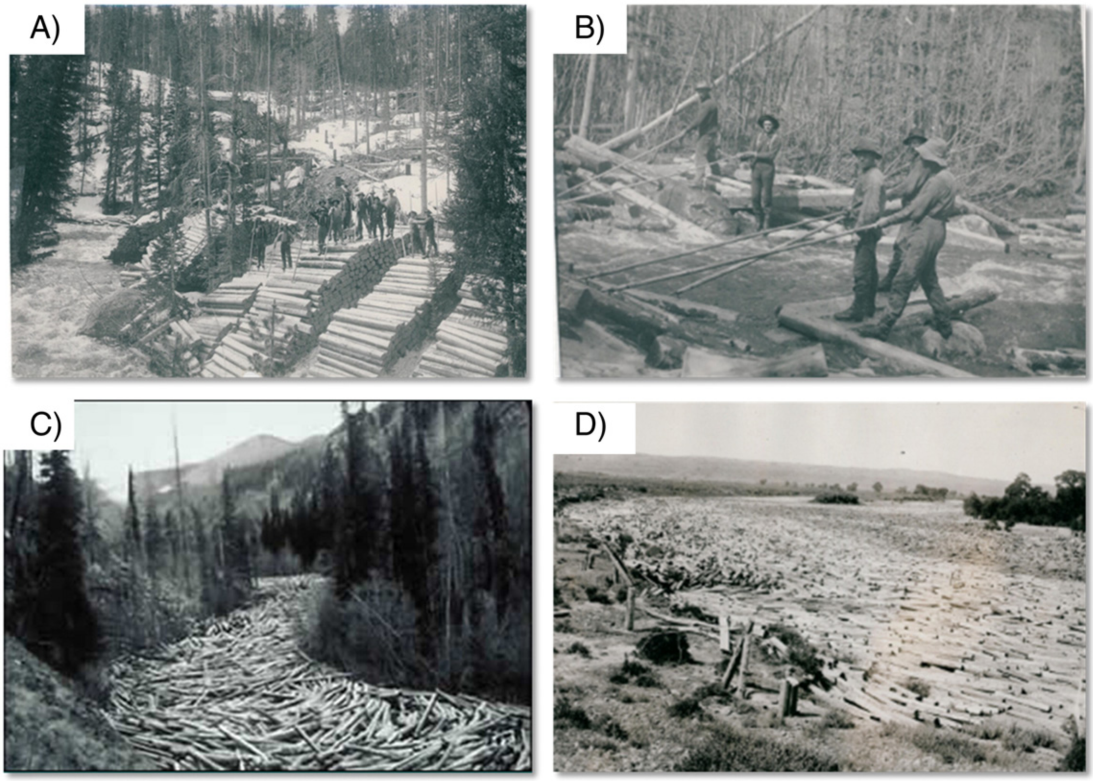

Fig. 1. Tie-driving in the Medicine Bow National Forest, southeast Wyoming. (A) Railroad ties were cut and stored in the riparian area adjacent to the stream channel. (B) Ties were floated downstream following peak flow. (C) Extensive tie jams were a routine event during drives. (D) Ultimately, tie drives accumulated in larger rivers to be delivered to processing centers downstream. Photographs courtesy of the Grand Encampment Museum.

Simon, 2001; Webb and Erskine, 2003) as well as transport potential (Abbe and Montgomery, 1996). Longitudinal patterns of wood throughout stream networks vary based on network position and have been attributed to a variety of drivers, including channel gradient, channel width, stream power, and drainage area (Wohl and Jaeger, 2009) — although local variations in channel and valley morphology can mask these drivers (Wohl and Cadol, 2011). This body of work has served as an integral foundation for understanding ecological functions such as habitat diversity and nutrient retention (Bilby and Likens, 1980; Bisson et al., 1987; Gurnell et al., 1995). Large wood has also received attention from the management community given the significant channel responses to wood removal and additions (Piégay et al., 2005; Chin et al., 2008; Lassettre and Kondolf, 2012). Despite the recent increase in research on wood dynamics over the last several decades, relatively little is known about wood loading in systems not subjected to pervasive historic anthropogenic disturbances.

Table 1
Observed responses in channel geomorphology to channel modifications related to timber floating activities.

Modification	Longitudinal	Cross-sectional	Planform	Sediment properties	Hydraulics
In-channel wood removal		– Widening and aggradation[a]	– Lower diversity of bedforms[a]		
Splash dams		– Channel incision[a] – Decreased floodplain connectivity[c]	– Fewer pools – Lower diversity of bedforms[a,b,c,d] – Decreased sinuosity[d] – Inundated riparian area[d]	– Increased erosion and scouring[b] – Bed armoring[a] – Decreased range of sediment sizes[b]	– Increased flooding upstream of dam[d] – Altered flow regime downstream of dam[d]
Feeder flumes			– Decreased sinuosity[d]		– Reduced hyporheic exchange[d] – Dewatering of backwaters, side channels, or other reaches[d] – Altered flow regime downstream of flume inlet and outlet[d]
Boulder removal	– Reduced channel roughness[d]	– Homogeneous channel depth[d] – Reduced channel roughness[d]			
Channelization	– Reduced channel roughness[d]	– Reduced channel width[e] – Decreased floodplain connectivity[e]	– Decreased sinuosity[e] – Homogeneity of bedforms[c,e]	– Loss of fine grain sediment[e]	– Altered flow regimes and decreased flood frequencies [c,d] – Increased flow velocity[e]

[a] Comiti (2012).
[b] Miller (2010).
[c] Helfield et al. (2007).
[d] Nilsson et al. (2005).
[e] Gardeström et al. (2013).