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Channel pattern and river-floodplain dynamics in forested mountain river systems

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Abstract

Channel pattern effectively stratifies the dynamics of rivers and floodplains in forested mountain river systems of the Pacific Northwest, USA. Straight channels are least dynamic, with relatively slow floodplain turnover and floodplains dominated by old surfaces. Braided channels are most dynamic, with floodplain turnover as low as 25 years and predominantly young floodplain surfaces. Island-braided and meandering channels have intermediate dynamics, with moderately frequent disturbances (erosion of floodplain patches) maintaining a mix of old and young surfaces. Return intervals for the erosion of floodplains increase in the order of braided, island-braided, meandering, and straight (8, 33, 60, and 89 years, respectively). A threshold for the lateral migration of a channel occurs at a bankfull width of 15–20 m. The most likely mechanism underlying this threshold is that larger channels are deep enough to erode below the rooting zone of bank vegetation. Above this threshold, channels not confined between valley walls exhibit channel patterns distinguishable by slope and discharge, and slope–discharge domains can be used to predict channel patterns. Meandering and braided patterns are most consistently identified by the model, and prediction errors are largely associated with indistinct transitions among channel patterns that are adjacent in plots of slope against discharge. Locations of straight channels are difficult to identify accurately with the current model. The predicted spatial distribution of channel patterns reflects a downstream decline in channel slope, which is likely correlated with a declining ratio of bed load to suspended load. Ecological theory suggests that biological diversity should be highest where the intermediate disturbance regime of island-braided channels sustains high diversity of habitat and successional states through time.

Keywords: Channel–floodplain dynamics; Channel pattern; Bank erosion; Bed load transport

1. Introduction

Geomorphologists, biologists, and ecologists have for decades used the classification of channel pattern as a common, cross-disciplinary language for describing the general character of reaches of alluvial rivers (Leopold and Wolman, 1957; Schumm, 1985; Ward et al., 2002). No one has explicitly linked these patterns to the biological and ecological processes that govern

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biodiversity in river–floodplain ecosystems (Lewis et al., 2000; Richards et al., 2002). Making this link first requires an understanding of the geomorphological template upon which river–floodplain ecosystems develop, including the processes that control the formation and persistence of floodplain surfaces. The geomorphological processes that we refer to here are mainly bank erosion and sediment deposition, which at the reach scale are seen as lateral movements of the channel across a floodplain. Processes of lateral movement include lateral migration, avulsion, meander cutoffs, and channel switching (Nanson and Beach, 1977; O'Connor et al., 2003). With each mechanism, the river erodes some patches each year while other patches accrete sediment and gradually rise in elevation above the river bed (Hickin and Nanson, 1975; Nanson and Beach, 1977; Salo et al., 1986; Hughes, 1997). Channel movements, thus, create a shifting mosaic of patches of habitat of different ages within the river corridor (Ward and Stanford, 1983). Spatial scale at which the mosaic can be observed varies with river and floodplain size, but typically ranges from 10^1 to 10^4 ha (Nanson and Beach, 1977; Salo et al., 1986).

This paper describes channel–floodplain dynamics in forested mountain river basins, using channel pattern as a basis for stratifying and predicting reach-level dynamics throughout channel networks. We have three main objectives. The first objective is to identify the threshold size of channel needed for lateral migration, which identifies where in the channel network a stream becomes large enough to erode forested floodplain surfaces and form new floodplain surfaces. The second objective is to illustrate that alluvial channel pattern predicts channel–floodplain dynamics in reaches large enough for lateral migration to occur. We describe these dynamics in terms of frequency of disturbance and formation of floodplain surfaces, as well as age structure of floodplain surfaces. The third objective is to predict the spatial distribution of channel patterns in mountain river networks. We develop a predictive model for channel patterns in the river network, map the distribution in several large watersheds (drainage areas ~2000 to 8000 km^2), and evaluate the accuracy of the predictive model. Finally, we discuss the implications of network-scale patterns for residence time of floodplain-stored sediment in mountain drainage basins, and for regulating ecological diversity.

2. Study area

This study was focused in a mountainous region of the Pacific Coastal Forest in North America (Fig. 1) that encompasses the Puget trough and adjacent mountain ranges. The Puget trough is oriented along a north–south axis, with the Cascade Mountains to the east and

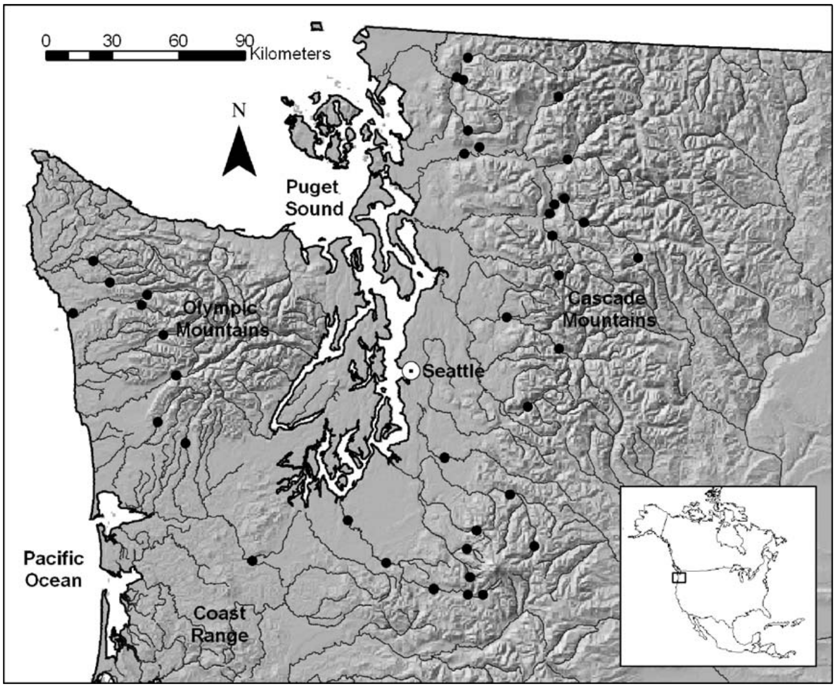

Fig. 1. Study area and site locations for analysis of patch dynamics by channel pattern.