Influence of Bank Afforestation and Snag Angle-of-fall on Riparian Large Woody Debris Recruitment[1]

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Abstract

A riparian large woody debris (LWD) recruitment simulator (Coarse Woody Debris [CWD]) was used to test the impact of bank afforestation and snag fall direction on delivery trends. Combining all cumulative LWD recruitment across bank afforestation levels averaged 77.1 cubic meters per 100 meter reach (both banks forested) compared to 49.3 cubic meters per 100 meter reach (one side timbered). Both bank afforestation and snag fall patterns generated significant differences in riparian LWD delivery, but there was no noticeable interaction. Scenarios with only one bank forested delivered 15 to 50 percent less LWD than their two bank counterparts. Snag fall patterns also produced statistically different LWD recruitment, with some registering only 35 to 52 percent of the most productive fall patterns. These results suggest testing the assumptions of random snag fall from two forested banks before modeling riparian LWD recruitment.

Introduction

Large woody debris (LWD) recruitment is critical to healthy riparian ecosystems (Bisson and others 1987, Dolloff 1994, Kershner 1997), making its recovery a primary goal of streamside management (Berg 1995, Kershner 1997). Surprisingly little work has been attempted on long-term recruitment dynamics, as research has concentrated on the quantification of riparian LWD and its ecological role. However, a growing interest in computer modeling of riparian LWD recruitment has prompted the development of some simulators in recent years (e.g., Bragg and others 2000, Murphy and Koski 1989, Rainville and others 1985, Van Sickle and Gregory 1990).

While creating a new riparian LWD recruitment model, we became concerned about some traditional assumptions. For instance, most efforts have presumed that both banks are equally forested. Although this may be true in mesic regions, some semi-arid areas have limited forest on some banks. Modelers have also assumed random snag fall without testing this premise. Random tree fall patterns can occur when failure is not influenced by either disturbances or geomorphology (Maser and Trappe 1984, Robison and Beschta 1990, Van Sickle and Gregory 1990). Although most riparian LWD simulations have applied this pattern, other distinct

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configurations are possible (Alexander and Buell 1955, Bragg and others 2000, Grizzel and Wolff 1998, Schmid and others 1985, Veblen 1986). Another biasing factor, tree lean, plays only a limited role in riparian LWD delivery (Hairston-Strang and Adams 1998). We decided to test the influence of different bank afforestation and angle-of-snag-fall patterns on riparian LWD delivery to the stream using computer simulation, which we hoped would improve the long-term prediction of riparian LWD recruitment.

Methods

Project Design and Assumptions

The riparian LWD recruitment simulator Coarse Woody Debris (CWD, version 1.4) was used to predict bankfull channel delivery. CWD is a post-processor to the Forest Vegetation Simulator (FVS) (Wykoff and others 1982). We will only briefly describe the most salient features of the models' interplay (Bragg and others 2000). FVS establishes, grows, and kills all simulated trees, while CWD drives LWD formation and channel recruitment. CWD takes dead trees, places them within the riparian zone, selects an angle-of-fall from a predetermined distribution, fells and breaks the snag, and assigns which pieces are recruited to the channel. Both disturbance-related and self-thinning mortality can be emulated (Bragg 2000). CWD randomly assigns tree locations in relation to the channel. Because the angle-of-fall pattern set by the user is fixed for the whole riparian forest, biased fall directions should be carefully designed to ensure consistency with local conditions. Depending on the need, CWD allocated the trees to one or two banks. This effort assumed LWD was greater than 10 centimeters in diameter and more than 1 meter long and was "recruited" to the bankfull channel if it extended at least 1 meter into this zone.

Modeled Stream Description

Dry Lake Creek, a second order stream about 60 km northeast of Jackson, Wyoming, on the Bridger-Teton National Forest, was exclusively used for these simulations. Along the sampled reach, Dry Lake Creek had a mean bankfull width of 5.5 meters, an average gradient of 3.5 percent, a mean elevation of 2,565 meters, and drained an upstream basin of 1,033 hectares (Bragg and others 2000). Riparian LWD volumes within this reach of Dry Lake Creek averaged 8.6 cubic meters per 100 meter (Bragg and others 2000). The predominantly Engelmann spruce (*Picea engelmannii* Parry ex Engelm.) and subalpine fir (*Abies lasiocarpa* [Hook.] Nutt.) forests along Dry Lake Creek averaged approximately 33 square meters per hectare of live basal area. Both banks along this particular reach were wooded, but for demonstration purposes, half of the simulations considered only one side was forested. A bankfull width of 5.5 meters and a streamside forest depth of 38 meters for each bank were also assumed. All simulations covered 300 years.

Statistical Design and Analysis

In this study, we tested five different snag fall patterns: (1) random (RND); (2) the tri-modal CWD default (DEF); (3) snags falling primarily towards the channel (TWRD); (4) a fall pattern quartering towards the channel (QRT); and (5) snag failure largely paralleling the channel (PRL) under two bank afforestation conditions (one [O] or both [B] forested) *(table 1).*

Table 1—*Treatment codes, descriptions, and predicted riparian LWD recruitment by bank afforestation and snag fall pattern.*

Treatment code	Description	Cumulative volume	Standard deviation
		---- m^3 per 100 m reach ----	
2 banks forested			
BRND	Random pattern	79.7	3.74
BDEF	Tri-modal (CWD default) pattern	78.4	5.18
BTWRD	Fall direction towards the channel	90.7	6.87
BQRT	Fall direction quartering towards channel	77.6	5.44
BPRL	Fall direction parallel to the channel	59.0	2.85
Pooled	Average of all 2 bank treatments	77.1	11.41
1 bank forested			
ORND	Random pattern	39.9	3.80
ODEF	Tri-modal (CWD default) pattern	38.4	2.60
OTWRD	Fall direction towards the channel	76.6	2.00
OQRT	Fall direction quartering towards channel	64.0	4.59
OPRL	Fall direction parallel to the channel	27.5	2.16
Pooled	Average of all 1 bank treatments	49.3	20.27

Because of the stochasticity in some CWD subroutines, 10 replicates were run for each snag fall pattern. Total LWD recruitment (in cubic meters per 100 meter reach) over the simulation period was compared to determine the cumulative significance of bank afforestation and snag fall patterns. Because of untransformable heterogeneity of variance and non-normal data distributions, the nonparametric two-factor extension of the Kruskal-Wallis (K-W) analysis of variance test and a multiple comparison using rank scores were used to identify treatment effects (Zar 1984).

Results

Both bank afforestation and snag fall direction significantly ($P < 0.05$) affected cumulative LWD recruitment to Dry Lake Creek, but there was no significant interaction between the two *(table 1).* Recruitment was always lower from streams with one forested bank: when averaged across snag fall patterns, having both banks forested delivered 77.1 cubic meters per 100 meter reach (standard deviation [SD] = 11.41), while one forested bank treatments averaged 49.3 cubic meters per 100 meter reach (SD = 20.27).

With only one bank forested, random (ORND), default (ODEF), and OPRL snag failure patterns yielded almost 50 percent less LWD recruitment than the same patterns (BRND, BDEF, and BPRL) when both banks were forested. Of these treatments, only the BPRL versus OPRL comparison proved statistically insignificant. OTWRD and OQRT declined only 15 to 20 percent from BTWRD and BQRT. However, consistently lower LWD delivery from only one forested bank resulted in the rejection of the null hypothesis of no effect of bank afforestation.

The tree fall pattern predominantly towards the channel (TWRD) produced the most LWD recruitment (regardless of bank afforestation), while the patterns paralleling the channel (PRL) yielded the least *(table 1)*. Even though BTWRD did not noticeably differ from BQRT, BDEF, and BRND when both banks were forested, it was significantly greater than BPRL. BTWRD ($P < 0.05$) and BRND ($P < 0.10$) also contributed more LWD to the channel than BPRL. OTWRD yielded more LWD than OPRL, ODEF, and ORND (35 percent, 50 percent, and 52 percent of OTWRD's cumulative LWD total, respectively), while OQRT provided more ($P < 0.10$) than OPRL. The ORND, ODEF, and OPRL treatments did not differ statistically.

Discussion

Although these bank afforestation and snag fall patterns are greatly simplified, their influence on LWD recruitment is statistically and ecologically meaningful. Random or tri-modal (i.e., CWD default) patterns produced intermediate levels of recruitment, while fall patterns biased strongly in particular directions resulted in either greater or lesser delivery, depending on bank afforestation and the predominant snag failure direction.

With only one forested bank, both the magnitude and the absolute volume of LWD recruited were substantially decreased *(table 1)*. Three of the simulated patterns (ORND, ODEF, and OPRL) yielded about 50 percent less debris than their well-forested counterparts. Rather than uniformly decreasing by half the LWD recruitment totals, the biased patterns tending towards the channel (OTWRD and OQRT) experienced a decrease of only 15 to 20 percent, suggesting that snags falling along the major axis are the most important component of riparian LWD recruitment.

Conclusions

This research showed that bank afforestation and snag angle-of-fall significantly influenced riparian LWD recruitment. Unfortunately, very few simulation studies have accounted for the impact of streamside forest coverage and snag fall when predicting long-term woody debris dynamics. With both banks forested, a greater volume of LWD was delivered over the simulation period, while snag failure patterns biased towards the stream outproduced random or other patterns not favoring the channel. Snag angle-of-fall became critical when only one side was forested and a strong unidirectional control (e.g., prevailing winds) was present.

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