Hydro-geomorphologic effects of large wood jams on a third-order stream (Tierra del Fuego, Argentina)

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Background

Logs and fragments of wood in channels (LW) play an important geomorphic and ecological role in woodland rivers (especially when organized in jams) because:

* Increase morphological diversity and complexity (mainly by means of pool formation);
* Increase habitats and biological diversity;
* Increase in-channel sediment storage (LW removal can greatly increase the sediment yield);
* Affect flow hydraulics (additional source of resistance)

Pool spacing is function of LW abundance, LW dimensions, channel slope, and bankfull width. However, for steeper streams, pool spacing is less sensitive to LW abundance than in moderate slope channels (Montgomery et al., 1995).

The present study focuses on the geomorphic role of LW elements and jams in an old-growth forested basin stream in the Southern Tierra del Fuego (Argentina). Wood jam type and dimensions are examined, along with adjustments of channel morphology (pool spacing).

Study channel

The study was carried out in the **Buena Esperanza stream** (Tierra del Fuego). The basin (12.9 km^2) elevation ranges from 0 to 1275 m a.s.l., and flows to the Beagle Channel next to the city of Ushuaia.

The region is temperate cold humid, and the hydrologic regime of the basin is glacionival. 34% of the basin is mainly covered by *Nothofagus pumilio* (along with *N. antarctica* and *N. betuloides*). The extreme climatic conditions leading to a very slow three growth Nothofagus. Even mature (>200 yr) trees have diameters generally < 0.5 m.

The Buena Esperanza is one of the few channels not impacted by North-American beavers (introduced in Tierra del Fuego in 1946), possibly because of the disturbing presence of the city of Ushuaia.

Field methods

In February-March 2006, 1.85 km of the main channel was topographically surveyed. 33 individual reaches were identified (uniformity in slope, width and LW abundance.

Channel variables measured in the field at each single reach include:

- mean bankfull width (B_{BF}), mean fluvial corridor width (B_{FP}),
- mean bankfull depth (H_{BF}), mean fluvial corridor depth (H_{FP}),
- number of steps higher than H_{BF}, and number of boulders larger than H_{BF},
- B_{BF}, B_{FP}, H_{BF} and H_{FP} were derived from 3 cross sections per channel reach.
- Bed morphologies (step height and pool length) were derived from the profile

- All wood pieces (D>0.1 m; L>1 m) were measured with a tape and a tree caliber.
- All visible pieces composing log jams were measured and classified relatively to their main function in the jam (key members and non-key members). Dimensions and origin of key members were noted along as qualitative information about the morphological effects of each jam. Each wood jams was classified following Abbe and Montgomery (2003).
- Geometrical dimensions (height H_J, width B_J, and length L_J) of each jam were taken in the field and the volume was estimated as $V_J=H_J*B_J*L_J$ (i.e. air-wood volume). For jams forming a step in the profile, drop height (z), scour depth (s), and pool length (L_p) were also measured.
- The volume of sediment stored by these jams was estimated as a solid wedge

Types	Distinguishing characteristics
In-situ (autochthonous)	Key member has not moved down channel.
Bank input	Some or all of key member in channel.
Log steps	Key member forming step in channel bed.
Combination	In-situ key members with additional racked WD.
Valley	Jam width exceeds channel width and influences valley bottom.
Flow deflection	Key members may be rotated, jam deflects channel course.
Transport (allochthonous)	Key members moved some distance downstream.
Debris flow/flood	Chaotic WD accumulation, key members uncommon or absent, catastrophically emplaced.
Bench	Key members along channel edge forming bench-like surface.
Bar apex	One or more distinct key members downstream of jam, often associated with development of bar and island.
Meander	Several key members buttressing large accumulation of racked WD upstream. Typically found along outside of meanders.
Raft	Large stable accumulation of WD capable of plugging even large channels and causing significant backwater.
Unstable	Unstable accumulations composed of racked WD upon bar tops or pre-existing banks.

Abbe and Montgomery (2003) jams classification

Types of jams in the Buena Esperanza

Log step
(D=0.45 m; L=12 m; Hs=1.3 m)

Flow-deflection jam
(LW volume=1.8 m^3)

Bar top jam
(LW volume=8.4 m^3)

Bar apex jam
(LW volume=1.4 m^3)

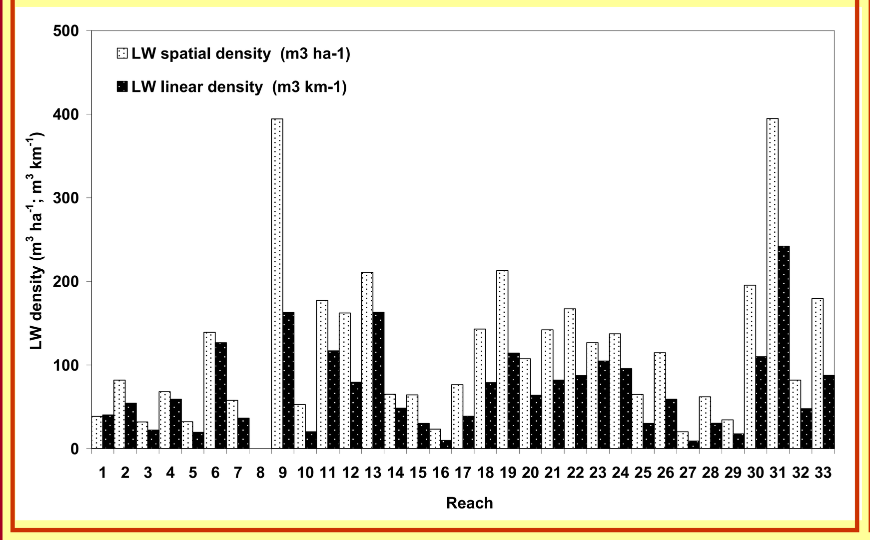
Bench jam
(LW volume=1.8 m^3)

Meander jam
(LW volume=0.8 m^3)

Results

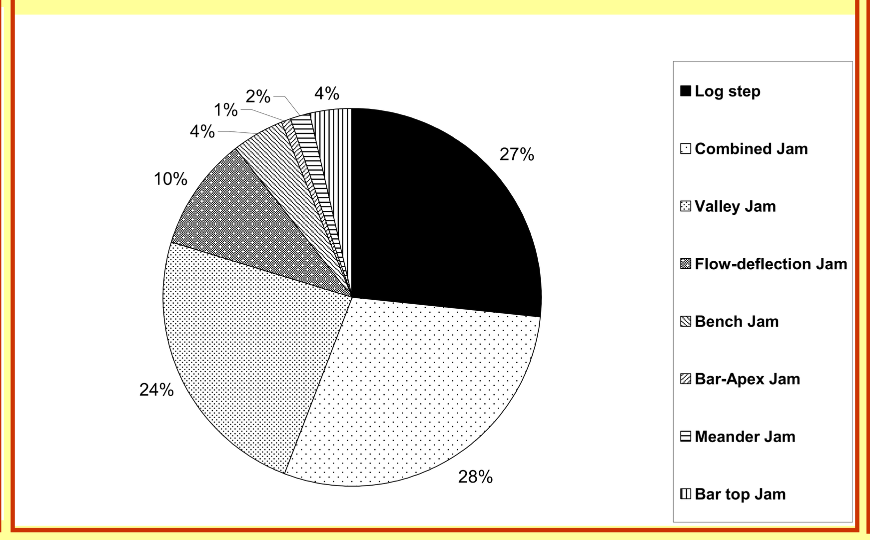
LW abundance

- Average spatial density: 121 m^3 ha^{-1} but there is a great variability between reaches (20 - 395 m^3 ha^{-1})
- No clear relationships between channel characteristics (BBF, BFP, S) and LW reach load
- The relatively low LW volume stored and the small diameter of the in-channel logs (0.18 m on average) is most likely caused by the extremely slow growth of Nothofagus in the Tierra del Fuego



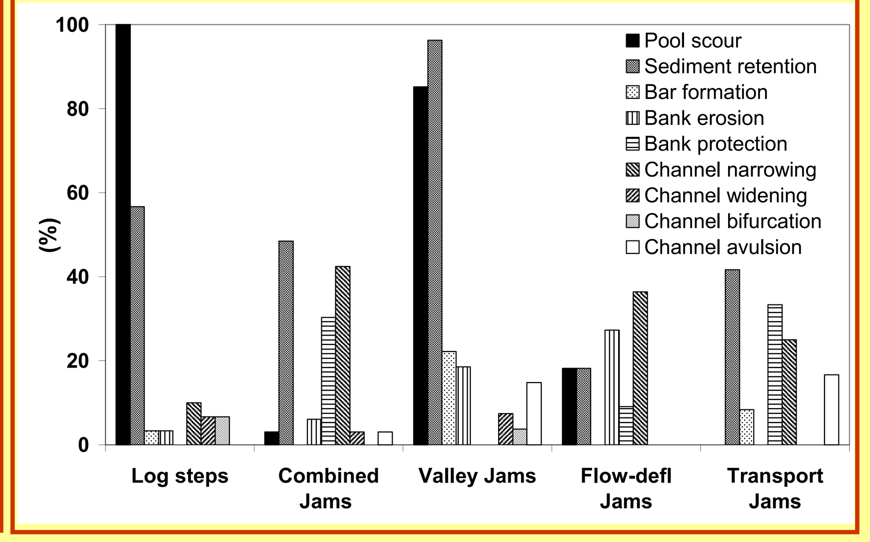
Characteristics of the 113 jams in the BE

- Abbe and Montgomery (2003) pointed out that autochthonous jams tend to occur most frequently in headwater channels. By the contrary, combination and transport jams are predominant (74%) in the BE.
- Valley jams in the BE are more frequent than what reported for Pacific Northwestern (3-4 per km)
- This is likely due to the small log dimensions in the BE, caused by the limiting climatic conditions



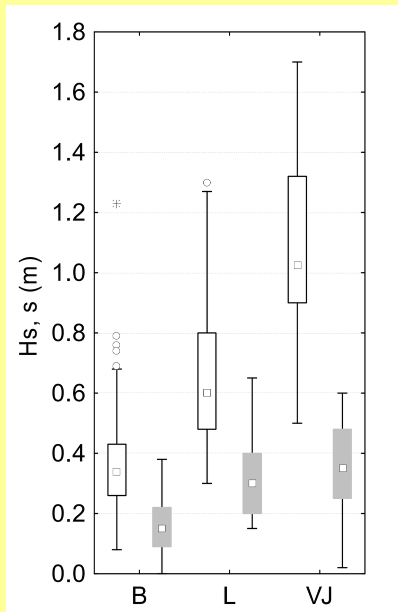
Jam influence on channel morphology

- All the log steps cause a downstream scour, but only 50% determine a sediment accumulation
- These two geomorphic effects characterize more than 85% and 96% of the valley jams, respectively
- Less than 20% of the flow deflection jams exhibits pool scour or sediment retention
- Flow deflection jams produces evident cross-section narrowing and consequent bank erosion



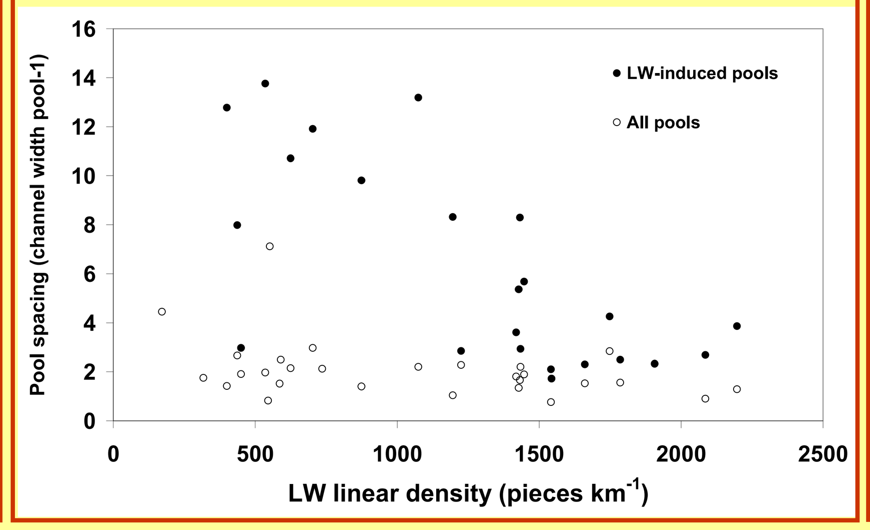
Jam effects on pool dimensions

- Step height (H_S) of valley jams (VJ; N=22) is higher than log (L; N=30) and boulder (B; N=123) steps
- A similar pattern is showed by pool depth (s)
- The 3 groups are significantly different for H_S and s
- Hs and s are positively correlated.



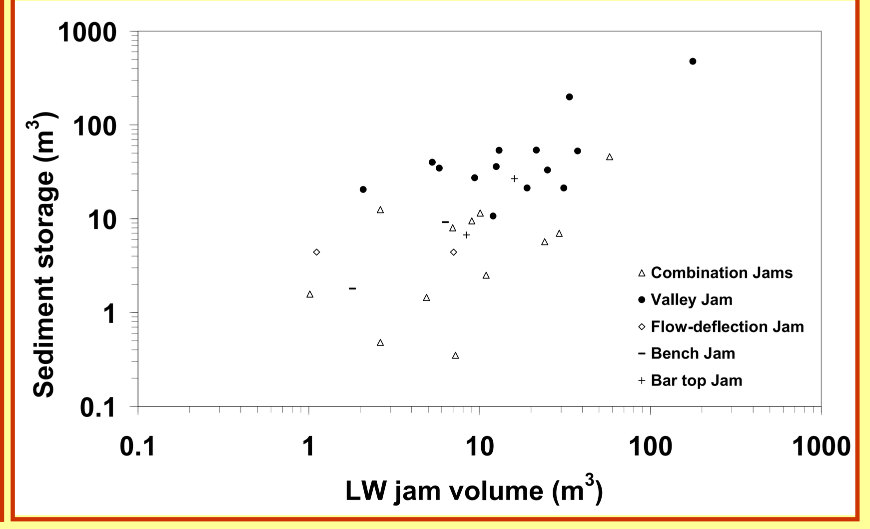
Jam effects on pool spacing

- Relatively scarce effects of LW load in pool spacing
- If only the spacing between LW-forced pools is considered, a clear inverse relationship with LW linear density becomes evident.
- Wood contribution to pool frequency increases with LW abundance, but it is secondary with respect to the number of boulder-related pools.



Jam effect on sediment storage

- 50% of the LW jams shows sediment retention
- Total impoundment is 30% of the channel length
- Volume of stored sediment is about 959 m^3 km^{-1}
- High correlation between sed. storage and LW load
- Valley jams have higher sediment retention ability
- Sediment volume stored by log step is highly correlated to step height



Overall, 30% of the 175 pools in the BE are caused by wood jams (less than what reported for small basins of New Zealand and Pacific Northwest).

At the reach scale, the percentage of LW-caused pools is highly variable, and no significant relationship with LW spatial density was found.

This confirms the scarce ability of single LW elements to shape pools when they are not clustered into jams in the Buena Esperanza channel.

Conclusions

Even if the number of in-stream wood pieces is comparable to what observed in other climatic areas, the slow growth of the nothofagus forest in the Tierra del Fuego causes a lower wood abundance in terms of volumetric load. Since the relatively small dimensions of the surveyed large wood pieces, almost the 70% of them demonstrated to have been fluvial transported and the also wood jams reflect the apparent dynamic of wood in the channel. Wood jams exert a significant influence on the channel morphology, representing almost the half of the drop caused by steps and being responsable for the creation of 30% of the pools. The LW-forced pool volume is strongly and positively correlated to the height of the LW jam, and a significant inverse relationship between pool spacing and wood density within is evident if only the LW-forced pools.

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