A conceptual model of riparian forest restoration for natural flood management

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Context

Riparian forests can have a substantial influence on the aquatic and terrestrial environments; influencing ecology, hydrology, channel form and processes, both directly and also indirectly through input of dead wood. As knowledge of the range of ecosystem services provided by riparian forests has increased, policy and practice in the US and Europe has turned towards protecting forests and encouraging forest restoration. With the flood prevention aspects of forests received a lot of recent attention (see Dixon et al, 2016).

However, to date there have been few comprehensive studies of riparian forest dynamics, and we cannot uncritically apply knowledge from upland forest plots due to the influence of disturbance from the fluvial environment. Therefore , we do not have a good understanding of the time scales over which ecosystem services, (including any flood alleviation effects) develop. We therefore need a better conceptual understanding of how riparian forests grow and how they interact with the fluvial environment through successional stages.

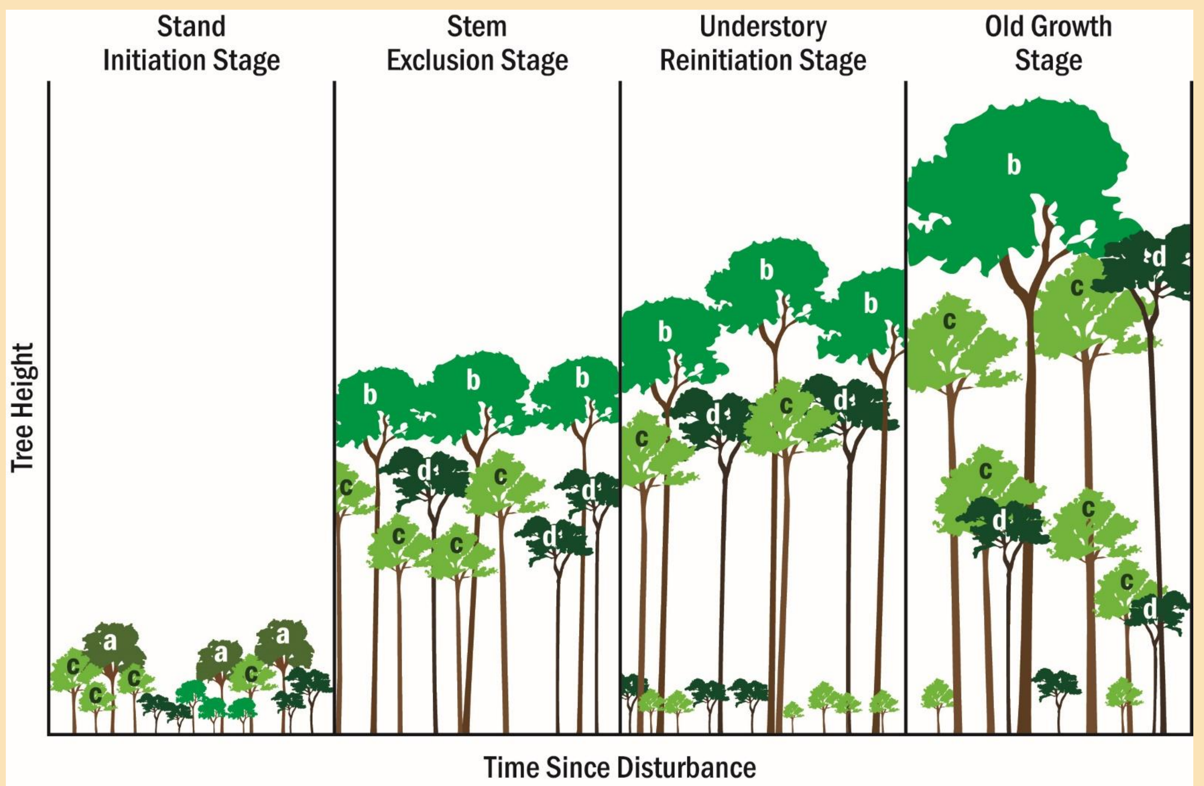

Figure 1 – A conceptual model of riparian forest growth from Naimen et al (1998). While this predicts growth of trees over time it doesn't include the influence of the forest on the stream environment

Methods

We used the USDA forest growth model NE-CWD (Lester et al., 2003; Nislow, 2010) to investigate riparian forest growth, including the build up of deadwood on the floodplain and in a stream channel. The model includes live tree and in-stream deadwood dynamics. The key objective is to formulate a conceptual model of how a riparian forest and in-stream logjams develop over time to aid understanding of restoration outcomes and trajectories.

Results

All model runs show a number of similarities in forest composition at 25 years, 50 years and 100 years from a bare earth scenario (post-restoration); prior to ~25 years there is negligible deadwood biomass either on the floodplain or in-stream. After 100 years all scenarios are at, or are asymptotically approaching, a maximum live wood biomass value, although this maximum value varies between scenarios. All model runs approach an equilibrium state at around 150-200 years where successful in-growth of new trees is dependent on gap phase regeneration following the death of larger specimens, so that both live wood biomass and numbers of trees within each size class are constant.

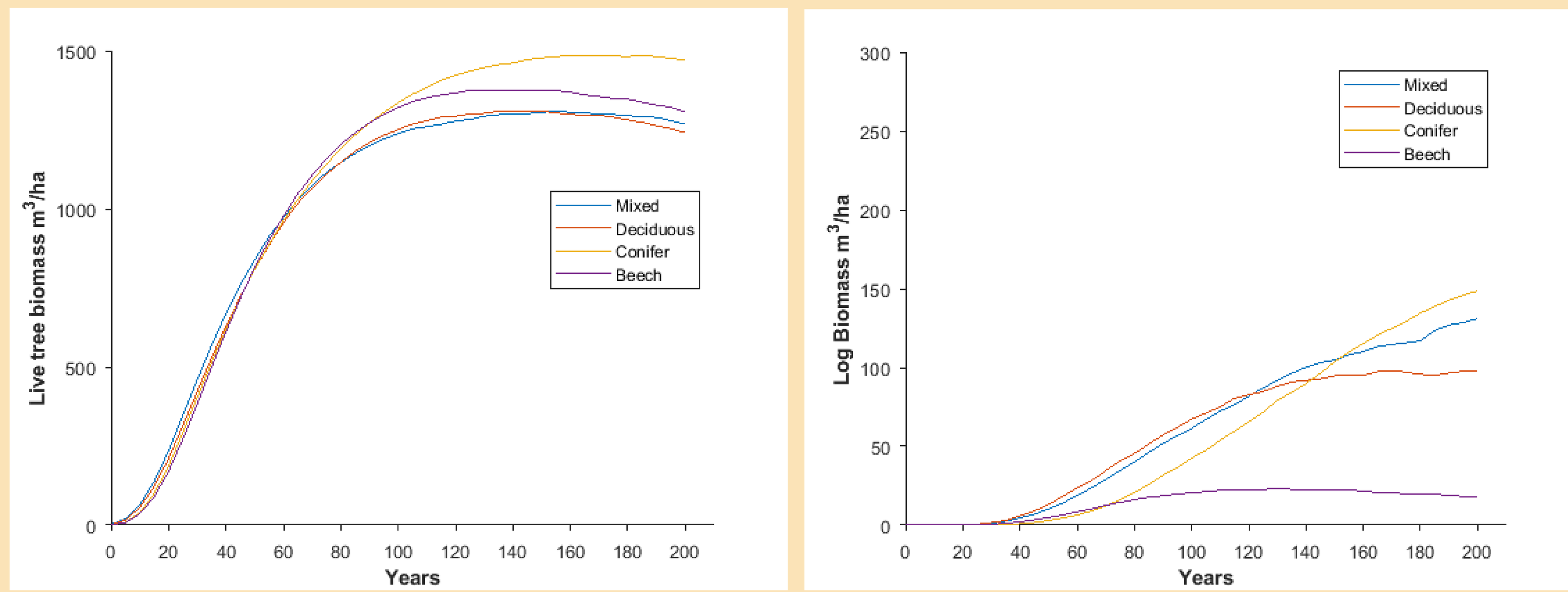

Figure 2 – Showing the gradual increase in live tree biomass, which eventually approaches dynamic equilibrium after ~100 years for all forest compositions. Logs do no start to appear until ~25 years in all simulations, and there are clear differences in how log biomass accumulates in different forest compositions.

With the combined model results we can propose a conceptual model for how a typical riparian forest, and associated forested stream develops during forest succession.

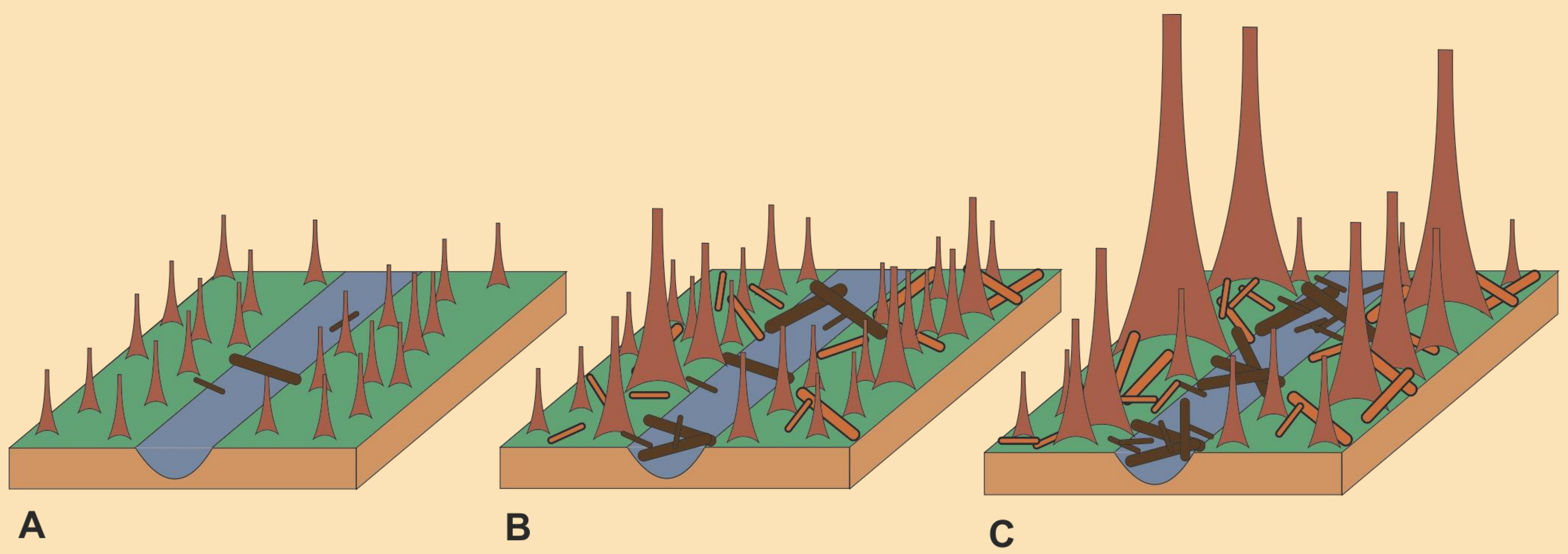

Figure 3 – (a) Conceptual model showing the ecohydromorphic development of a forested stream. A – riparian & floodplain forest dominated by small polewood, some wood enters channel, but is of insufficient size to be stable large wood, or form logjams (c.0-30yrs). B – Larger trees being to appear, some competition related mortality, dead wood begins to build up on floodplain/riparian zone and logjams (and associated processes) begin to appear in channel (c.40-100ys). C – Mature forest, mix of large mature trees and smaller specimens appearing through gap phase regeneration. Abundant, large in channel wood from wind thrown trees and those recruited to channel via bank erosion, anchoring stable logjams. High degree of channel-floodplain connectivity across riparian zone.

Key Points

- Full range of ecosystem services provided by riparian forest do not appear until >50 years
- In young forests in channel dead wood is too small and is transported away
- Logjams do not appear until >40 years

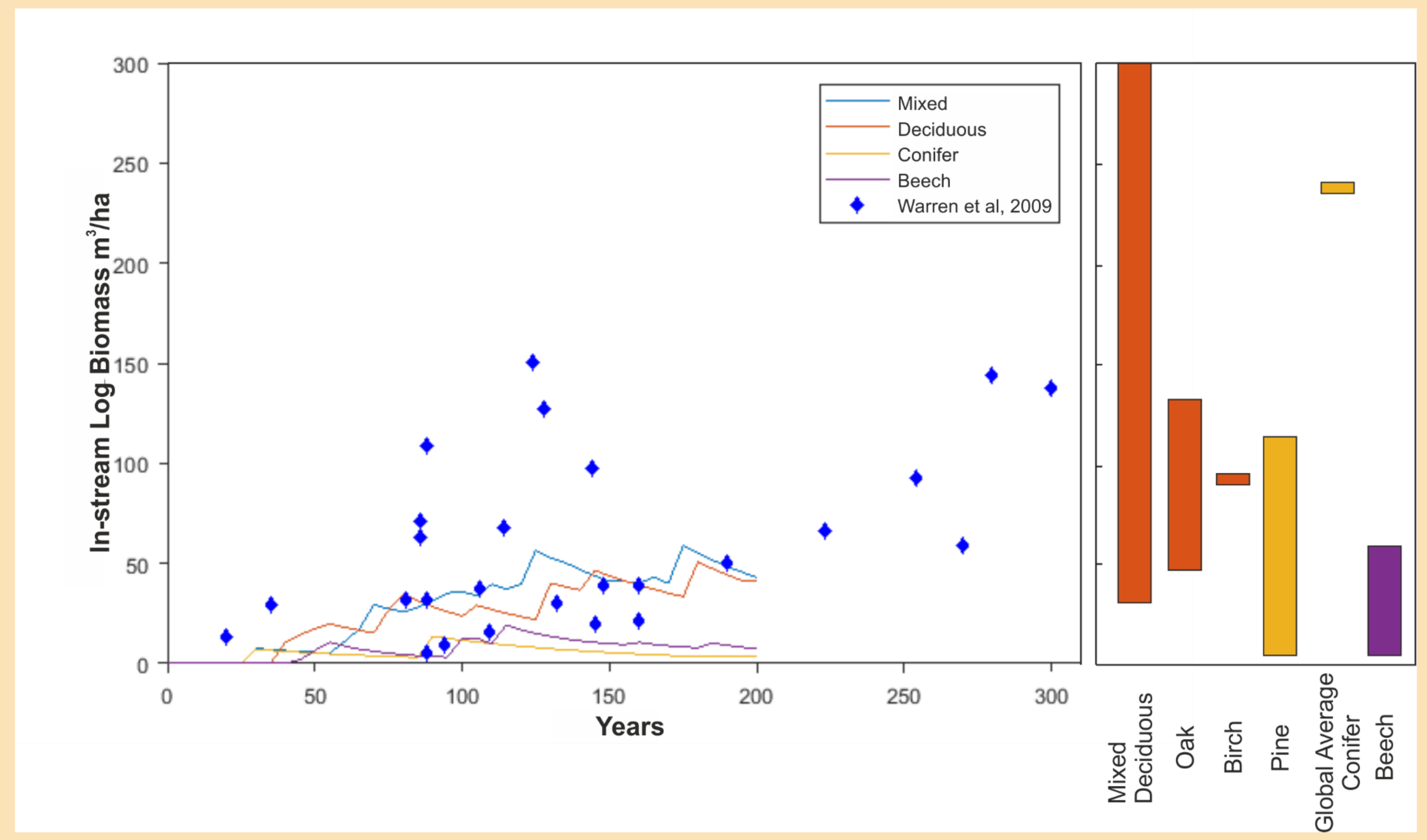

Figure 4 – Validation of modelled in-channel deadwood values against data from the literature.

Conclusion

This study has important implications for riparian forest management, particularly in relation to restoration. The key finding is that it takes a significant time period for riparian forests to become mature enough to generate stable logjams in the channel and so mediate the full range of ecosystem services large wood can provide to the channel and floodplain.

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