Partnering with Nature's River Restorers for Sustainable River Management

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Extended Abstract

River management based entirely on physics-based science has proven to be unsustainable, evidenced by the fact that the problems river management is intended to solve (e.g. flood hazards, poor water quality, channel instability) have patently not been solved, while long-term deterioration in aquatic environments continues to reduce the capacity of rivers to go on meeting the expanding needs of society (Gilvear et al. 2016). In response to this emerging truth there has, over the past two decades, been a shift in river management towards restoration. However, at least to date, ecological, morphological and societal benefits achieved using this approach have been underwhelming (Palmer et al. 2014). We believe this is because restoration over-relies on the same physics-based science as past management; focusing on analysis of the power of flowing water in relation to the resistance offered by channel boundary sediments and attempting to design stable, alluvial channels.

This form of analysis has long been characterised by Lane's Balance (Lane 1956), a visual representation of how imbalance between stream power and sediment load leads to aggradation or degradation. It is now possible to solve the governing equations of water flow and sediment transport in multiple dimensions and over long reaches and periods, yet the focus of physics-based analyses remains in-bank flows along single-thread channels with straight or meandering planforms. This despite the fact that we now know meandering streams with bankfull discharge return periods of 1.5 or 2 years were not prevalent prior to human modification of natural streams and are, in fact, often the legacy of historical, anthropogenic river engineering for hydro-power, flood control or land drainage (Walter and Merritts, 2008). In light of this revelation, innovative restoration approaches are challenging the orthodoxy that single-thread, meandering channels necessarily constitute the best 'target' morphology (Cluer & Thorne, 2014). Practitioners propose instead that rivers with functional floodplains and adequate sediment supplies are better served by restoration of multi-channel, anastomosed planforms that better represent pre-disturbance forms and are fully-connected to the surrounding, wetland-floodplain systems (Powers et al. 2018).

If future river management and restoration is to reverse long-standing declines in river functions, it is necessary to re-envisage what it means to design a channel, focusing less on balancing water and sediment flows and more on situating channels within complex channel-wetland-floodplain corridors that support balanced and healthy biomes. We define this as *Biomic River Restoration*. Our new vision of a biomic river can be illustrated by amending Lane's Balance to acknowledge and incorporate the influence of life in the river on the balance between aggradation and degradation (Figure 1).

Biomic restoration recognises that biological processes interact with alluvial processes, with direct consequences for both the physical form of the river and its response to disturbance. Organisms work constantly to improve their own life chances and those of their species (Darwin, 1859). This endows disturbed natural fluvial systems with a self-healing capacity, driven by successional processes that follow a major disturbance to facilitate ecological recovery that, in turn, promotes physical recovery to a new, dynamically meta-stable state (Castro and Thorne, in press). It is vital that the rivers we manage and restore are resilient in an increasingly uncertain future. This requires restoration outcomes that are adaptable not only to changes in the flow and sediment regimes, but also to changes in local, catchment and regional land-use. Adaptive capacity is maximised when restoration creates fluvial and ecological systems that correspond and co-evolve, building resilience to disturbance however the future unfolds.

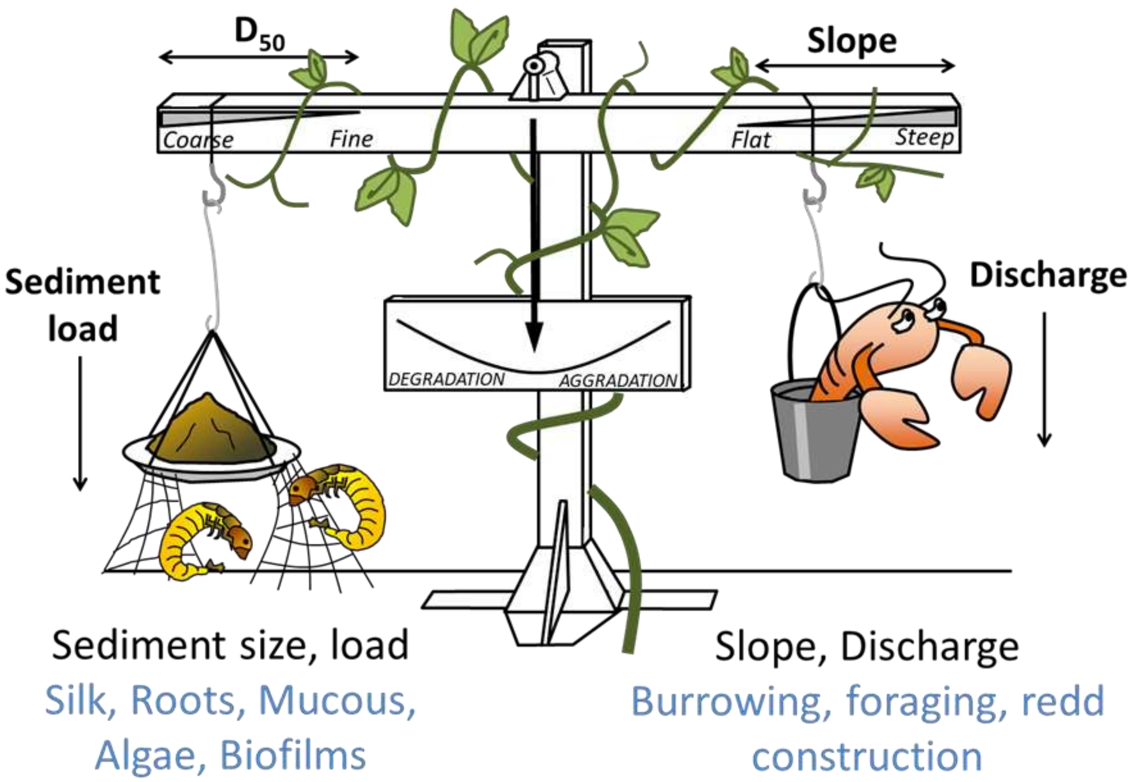

Figure 1: Lane's Balance (1955) has been used as a visual representation of the physics-based paradigm of equilibrium, degradation and aggradation in alluvial rivers for over 60 years. It describes how stable channels occur where sediment load and size are balanced by stream power. Here, we propose an alteration, which represents the important roles that the river's ecosystem also play in determining stable channel form.

Elements of the biomic approach are already in practice. For example, re-introduction of trees and large wood to resist erosion and store sediment in alluvial channels are established restoration techniques [Roni et al. 2014]. However, there is still a tendency to use wood as a 'natural' alternative to concrete or riprap when stabilising a naturally retreating bank. The natural interplay between vegetation, channel form and channel dynamics is more subtle than this; riparian tree species co-evolved with river planforms, as evidenced by sedimentological data showing that, until vegetation with substantial root systems colonised the land, most rivers were wide, sheet flows with braided planforms (Davies and Gibling, 2010). Only after the global spread of trees during the Devonian and Carboniferous periods did rivers develop gradually-shifting, meandering and anastomosed patterns; an association that was interrupted by the Permian-Triassic extinction (when over 90% of life, including plant life was obliterated and following which rivers reverted to sheet-braiding for about 5 million years). Multi-thread planforms then predominated until valley-bottom forests were cleared and rivers were confined to single channels by humankind during the last few centuries.

The influences of some macrofauna, such as cattle, beaver and salmonid fish on fluvial processes have also been recognised for some time. However, the impacts of these organisms are often regarded as atypical, being responsible for localised departures from normative, alluvial forms attributable solely to flowing water. Actually, the impacts of animals on fluvial processes are anything but localised – they are pervasive and fully integrated into the fluvial system, because animal life in rivers is naturally abundant and diverse, and many animals are known to alter river conditions purposefully. While the biogeomorphic effects and restorative utilities of trees and large mammals are gaining recognition, the influence of small animals is rarely considered, despite their ubiquity in temperate and tropical streams. More research is needed, but early indications are that the biogeomorphic impacts of these organisms are also significant. For example, in gravel-bed rivers, natural densities of caddisfly larvae can increase the critical fluvial shear stress required to mobilise bed sediments by 33 to 45% (Johnson et al. 2009), reducing the frequency and magnitude of bed material motion.

Perhaps the best demonstration of the significance of animals to river forms and processes occurs when organisms are either extirpated, or introduced outside their native ranges. Under these circumstances, biogeomorphic impacts tend to be negative. For example, extirpation of wolves from Yellowstone National Park lead to a trophic cascade that resulted in system-wide river widening because riparian willows were overgrazed by an explosion in the elk population (Beschta and Ripple, 2006). In the UK, deleterious burrowing into the beds and banks of rivers by invasive Signal Crayfish demonstrates the vulnerability of rivers and ecosystems to damage by introduced species (Rice et al. 2014). Mismanagement of river biomes has potentially disastrous geomorphological implications and, in these cases, managing the cause of the problem by restoring balance in the ecosystem provides the only sustainable, long-term solution.

Nature’s river restorers work 24/7, 365, without pay and, if they appear to work as if their lives depended on it, they do - because it does. However, they do have fundamental needs, including a liveable flow regime, space to work, a ready supply of suitable food, and support from life lower in the trophic system.

It is impractical to attempt to restore the natural, pre-disturbance flow regime in all but a relatively small number of rivers and, in any case, climate change means future flow regimes will differ from those of the past. Fortunately, native species evolve to tolerate and thrive under naturally-variable conditions and therefore, providing a liveable flow regime in regulated rivers usually requires only that seasonal patterns of instream and overbank flows are approximated (Hall et al. 2009). The biomic approach further requires conserving or restoring a river’s capacity to absorb and recover from extreme events, by giving it sufficient room to flood, to entrain, transport and deposit sediment, to allow riparian vegetation to establish on new surfaces, and to recruit large wood from trees growing on gradually eroding banks (Kondolf, 2011).

Nature’s river restorers cannot do their work without a functional food web. In this context, it is necessary to recognise that it is the microbial community that underpins provisioning of the biome, by creating, cycling and recycling the chemicals, nutrients and minerals that enable primary production to support the food web (Mendoza-Lera & Datry 2017). Additionally, the role of the ‘Hidden Half of Nature’ in supporting the immune systems of plants and animals is increasingly recognised (Montgomery and Biklé, 2015). Sterile sediments often used to rebuild floodplains and create in-channel features all too often create lifeless, abiotic matrices. Vibrant microbial communities are necessary to support the higher lifeforms needed to restore degraded fluvial and floodplain environments, and failure to consider this when restoring rivers is likely to impede success.

Unless rivers are being truly re-wilded, the range of higher lifeforms necessarily involved in delivering successful restoration outcomes include ourselves, and there certainly remains a role for suitably qualified, human restoration engineers, especially those with an appreciation of the social and biomic, as well as hydrological and morphological contexts, of their designs. Recognising this, we propose that river restoration engineers and designers who take a holistic view of the river and watchfully partner with Nature’s river restorers are more likely to deliver resilient river futures than designers who continue to rely on the physics-based analyses used to inform most restoration designs to date.

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