Restoration on the Margins – the efficacy of using gravel augmentation to offset habitat loss in sediment-poor upland channels

Restauration des marges - éfficacité des recharges en gravier pour compenser la perte d'habitat dans les chenaux d'altitude pauvres en sédiments

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Westcountry Rivers Trust

South West Water

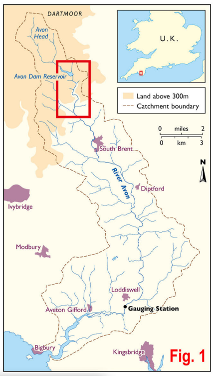

Fig. 1

INTRODUCTION

In upland channels, loss of aquatic habitat for salmonid spawning and rearing is often related to the depletion of alluvial sediment from the channel bed, especially below large dams. One practicable mitigation is to manually replenish gravel to the channel bed – gravel augmentation. This 'prompted recovery' approach is frequently practiced even though little is known about the dynamics of sediment transfer and habitat response in steep, mixed alluvial-bedrock channels. Addressing this concern, gravel augmentation in the River Avon (Devon, UK) has been monitored using seismic impact plates, RFID-tagged particles and detailed channel bed mapping to establish particle mobility, dispersal distances and settling locations relative to the flows received.

STUDY AREA

The River Avon (Fig.1) rises at 460m on a granite massif (Dartmoor), and flows approximately 40 km to the sea. The upper catchment produces naturally low rates of coarse sediment supply while mainstem flows are regulated by the 33-m high Avon Dam (built 1957). Situated 4 km below the dam, the focal study reach contains a patchy matrix of coarse gravel and cobble deposits interspersed by large boulders and areas of exposed bedrock. The high relative roughness of the immobile boulder bed creates a chaotic pattern of energy expenditure: gravels and sands congregate in the stoss and lee of boulders and in the channel margins where they can be deposited above low flow elevations (Fig.2). Patchy sediment storage suggests a supply-limited reach in which transport thresholds are characteristically bi-modal.

Gravel augmentation has been practiced annually since autumn 2014, using size-graded sub-angular granites derived from a local quarry (Fig.3). At the focal study reach 25 – 42 t of material has been added each year. In this flashy environment, mobilization commences with the first high flow (Fig.4).

Fig. 2


Fig. 3


Fig. 4

Methods

1. **Process stimulus:** 15-minute gauged flow elevations
2. **Habitat base maps:** detailed facies mapping, v, d, Wolman D50
3. **Gravel auditing:** walk-over surveys: GPS located deposit size, relative channel location and elevation, retention feature, age
4. **Sediment Dispersal:** RFID: epoxy-fitted 23 mm half-duplex PIT tags (Fig.5), WY2015: 150 particles (42-58 mm), WY2017: 200 (35 mm), located to ± 1 m using hand-held reader (photo), post-processed Trimble Geo7X GNSS with Trupulse offset. 180 m reach
5. **Volume:** 'Benson' type seismic impact plate (Fig.6): timing, frequency, intensity 10 mm detection threshold; 2.5 min intervals, 10 m downstream of augmentation pile, situated in primary transport chute (see Downs *et al.*, 2016, Soar and Downs 2017)

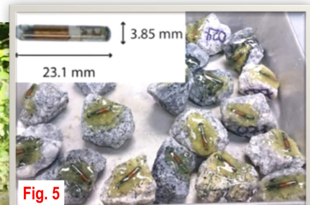

Fig. 5

Fig. 6

CHARACTERISTICS OF BEDLOAD SEDIMENT TRANSPORT

FLOW CONTEXT: WY2015 few high flows, WY2016 wet but no exceptional flows, WY2017 very dry but included a two-year flood event.

TAG RECOVERY RATES: Complex terrain leads to relatively low returns: ~50% of tracers recovered in the first survey in WY2015 (4 months after augmentation), and 53% in WY2017 (3 months). An extended survey in 2016 (180-410m downstream) suggested that unrecovered tracers were likely transported beyond the focal reach rather than having been missed by the surveyors or subject to deep burial. In WY2017, some particles had travelled up to 300 m in a 3-month period that included a two-year flood event.

IMPACT PLATE RECORDS: ~58% of augmented particles struck the plate in WY2015, and 40% in just 2.5 months in WY2017 before the plate was dislodged by a high flow (Fig.7). As this results refer to returns from a single impact plate, they represent minimum mobilities.

MOBILITY CHARACTERISTICS: In WY2015 there was almost no size-selectivity in particle transport distances with either size (range 30–90 mm) or mass (range 80–1000 g): 10% explained variance in January 2015 fell to 3% the following summer (Fig.8). Comparisons of particles recovered per metre inversely with channel gradient and stream power fared little better (R^2 = 0.15 and 0.18, respectively).

EVENT-SCALE MOBILITY: Total impacts per high flow event and the energy applied for 19 events in WY2015 were strongly related (R^2 = 0.77) and highly non-linear (power exponent of 3.95) (Fig.9). Such proportionality of sediment transport with available energy is consistent with other studies (*e.g.*, Mao and Lenzi 2007; Schneider et al. 2014). Outlying data points suggested more impacts than expected during after augmentation (*i.e.*, underprediction); overprediction later in the year suggested volumetric exhaustion of (augmented) sediment supply.

MORPHOLOGICAL IMPACT OF AUGMENTATION: extensive gravel mapping suggested gravel deposition is promoted by the presence of large roughness elements (boulders, large wood), in sheltered channel embayments including above the low-flow channel (Fig.10), and on lateral bars related to channel curvature. Surface grain sizes in control sites have reduced from 55 mm to 50 mm. Particle deposits are becoming increasingly patchy as dispersion continues.

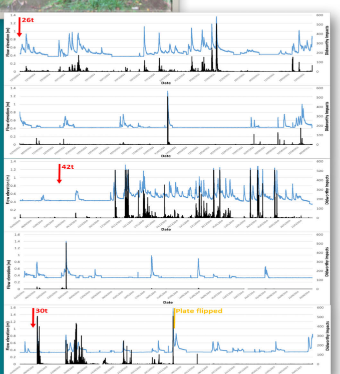

Fig. 7

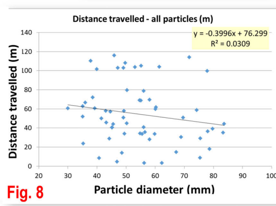

Fig. 8

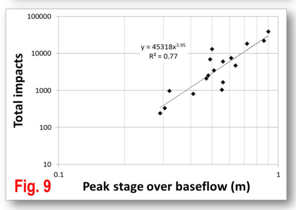

Fig. 9

CONTROLS ON SEDIMENT DYNAMICS

To date, the results indicate that cascading river reaches are supply-limited and have a bi-modal transport character wherein gravel-sized particles are highly and equally mobile. Tagged rocks suggest that depositional **patterns are controlled by the *intrinsic* fan-like transport properties of coarse sediment dispersal (Lisle *et al.* 2001; Cui and Parker 2005; Hassan *et al.* 2013) (Fig.11) overlain by local controls provided by the presence of localized large roughness elements (boulders, large wood), sheltered channel margins and channel curvature.** The result provides an elemental explanation for the apparently 'chaotic' patterns of sediment deposition in steep, alluvial-bedrock channels.


Fig. 10

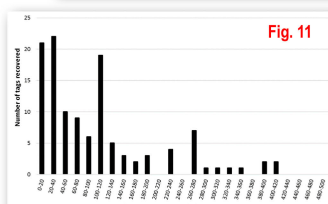

Fig. 11

GRAVEL AUGMENTATION IN SUPPLY-LIMITED UPLAND CHANNELS

High particle mobility (>300 m in 3 months possible) despite lack of large flows

- **Augment particles upstream of a depositional zone for focused reach-level benefits Augment coarser sediment downstream of the first unregulated tributary for dispersed habitat gain?**

Habitat improvements are inexorably bound to the presence of retention features to reduce sediment 'loss'

- **In steep upland channels with 'small' dams, the challenge is sediment retention, not mobilisation. Use knowledge of depositional pattern controls (see above) and add retention features to maximise impact**

Deposits perched above the channel have very limited short-term habitat value, but represent mechanism for post-dam channel capacity reduction in otherwise supply-limited rivers

- **And possibly indicate of channel 'alluvialisation' as channel becomes increasingly gravel rich**
- **The channel bed is fining through augmentation (from 55 mm to 50 mm in monitored patches)**

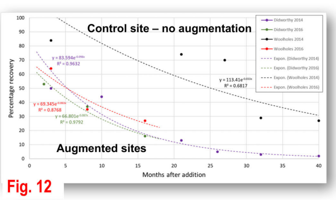

Fig. 12

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