# The Power of Biology in River Environments

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**Introduction:** Animals have been shown to be able to move sediments in rivers (e.g. Rice et al. 2016); however, understanding of their significance relative to physical processes remains limited. For plants, simplified metrics of impact, such as quantification of primary productivity, indicates biological energy in the environment greatly exceeds geological and geomorphological energy (Phillips, 2009). No equivalent exists for rivers or for animals. Therefore, this study aimed to investigate methods of quantifying the power of biology in river environments associated with invertebrate fauna.

**Methods:** Two methods were employed to quantify the energy expenditure of invertebrates. The first consisted of measuring invertebrate abundance at 11 sites in England in spring and autumn 2018, and calculating the total energy (calories) associated with each community. This represents a theoretical maximum energy associated with the community, similar to primary productivity for plants used by Phillips (2009). The second method placed a single Signal Crayfish (*Pacifastacus leniusculus*) in a sealed tank and estimated energy expenditure as a function of respiration rate (i.e. oxygen (O2) depletion). As a validation, the substrate consisted of marbles of uniform size and weight (Figure 1), and so the energy required to move a single marble a set distance was known. The total number and estimated distance of each marble movement was recorded, giving a second estimate of energy expenditure.

**Figure 1:** *Crayfish on bed of marbles.*

**Results:** Invertebrates at the 11 sampling sites were abundant, with between 723 and 3229 individuals of 16 to 33 taxa. The unit power (Watts/m$^2$) was broadly similar between spring and autumn communities and were an order of magnitude higher than the power associated with discharge in the highest 10$^{th}$ percentile (Q10) (Figure 2). Only a proportion of that energy would be used for sediment alterations; however, the same is also true of the stream power.

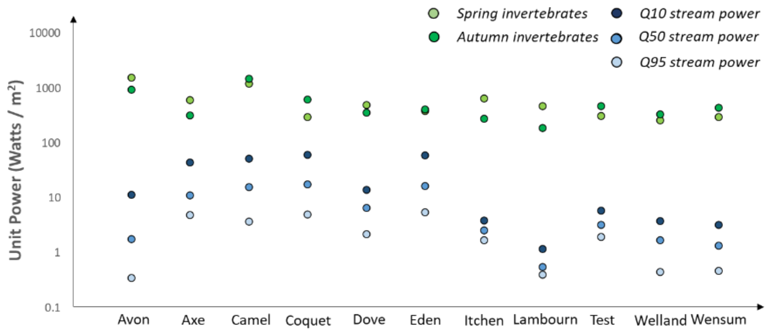


**Figure 2:** *The stream and invertebrate power estimated at 11 sites.*

Oxygen measurements in aquaria indicated that crayfish expended approximately 6 Joules per hour (i.e. 0.0017 Watts). Crayfish moved 300 marbles an average of 6 grain diameters, which indicates a power 0.0015 W m$^{-2}$, corroborating the O2 measurements. Extrapolating to crayfish populations recorded in the River Nene (Rice et al. 2016), indicates crayfish, on average, expend 0.08 W m$^{-2}$ per night. In the tributary of the Nene where the crayfish activity was recorded, the stream power associated with Q10 is 37 W m$^{-2}$ and the Q95 is 1 W m$^{-2}$, indicating crayfish power is orders of magnitude smaller than that associated with the flow in this river.

**Discussion and Conclusion:** The BSG grant enabled the purchasing of equipment and field work, which has resulted in international conference presentations (e.g. EGU) and pump-primed ongoing work on this topic. The results indicate that calorific content of invertebrates represents an energy source much larger than stream power but, experiments with crayfish suggest only small proportions of that are likely to be expended on sediment alterations. However, the same is true of stream power and so direct comparison is complex. Also, past work has shown that crayfish can move sediments 40 mm in diameter (Johnson et al. 2010), which would require 30 W m$^{-2}$ stream power to mobilise (Petit et al. 2005). Therefore, crayfish are likely to use their power more efficiently when moving sediment than the flow, further complicating direct comparisons between biological and physical processes.

Johnson et al. (2010) 10.1016/j.geomorph.2010.07.018; Petit et al. (2005) 10.1016/j.geomorph.2004.12.004; Phillips (2009) 10.2475/04.2009.01; Rice et al. (2016) 10.1002/2015JF003726