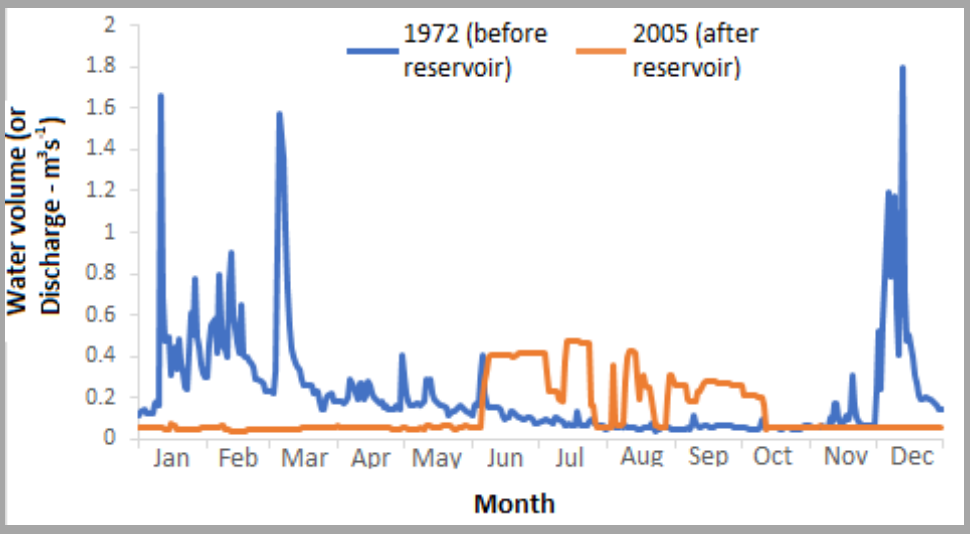
RRC Research Blog 1 date 04/08/2022: Ecological responses to flow regime alterations

By Dr James C. White

River flow regimes, or the variability of water volumes over time, have been transformed worldwide by various human activities. This includes the construction of dams for public water supply and energy demand; surface water and groundwater withdrawals for public water supply and irrigation; and land cover changes like paved, impermeable surfaces. Such activities can alter river flow regimes and lead to extreme hydrological stress, including severe floods and droughts. The image below provides one example of this from Shell Brook (West Sussex), where the construction and storage of water in Ardingly reservoir reduced river flow quantity and variability over the year.



A 'hydrograph' showing changes in how water volumes vary over time before and after reservoir creation (adapted from Fig. 3a in Wilby et al., 2017. pp. 5).

Flow regime modifications have severe consequences for river ecosystems. For example, immature specimens (nymphs) of the 'Scarce purple dun' mayfly (*Paraleptophlebia werneri*) preferentially inhabit winterbourne chalk streams that dry for approximately half the year (White *et al*., 2018). The adults of salmonid species like brown trout (*Salmo trutta*) and Atlantic salmon (*Salmo salar*) use high flow events as a migratory cue, while the juveniles prefer smaller water volumes and the associated lower flow velocities (Acreman and Ferguson, 2010). As such, changes to natural flow regimes may prevent organisms completing their life cycles.

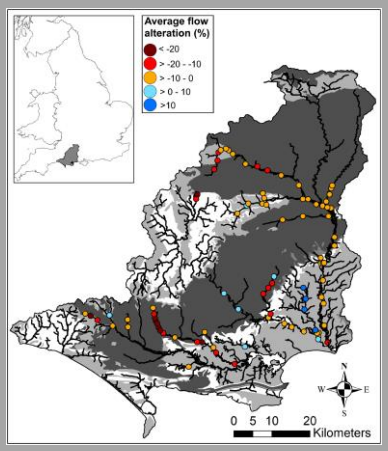
Images of a organisms inhabiting rivers that depend on natural flow regimes: scarce purple dun mayfly nymph (left) and Atlantic salmon and brown trout (right).

Dr James White - Research interests

I am a freshwater ecologist with a particular passion of studying macroinvertebrates – the core of river ecosystems. My enthusiasm for these little critters started when studying my MSc at the University of Birmingham. This passion grew whilst undertaking my PhD at Loughborough University where I examining the effects of flow regime alterations on macroinvertebrate communities, which is now my primary research specialism.

Me showcasing macroinvertebrates to the 'Swansea ramblers' on the bank of the Brynmill Stream, Swansea.

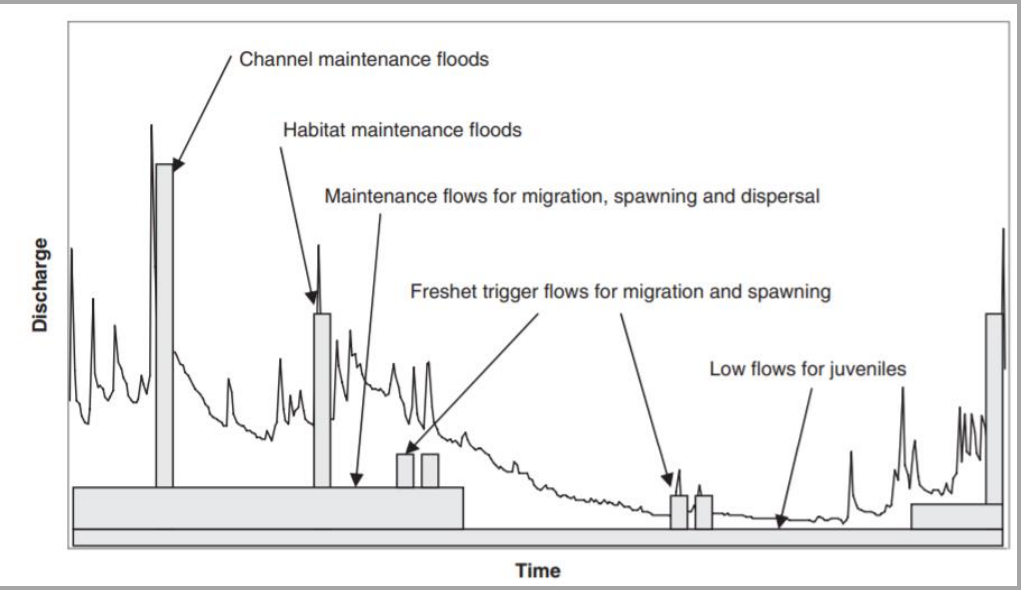
The final paper from my PhD published in *Water Research* in 2021 (White *et al*., 2021), where I worked with Wessex Water plc. on a project based on chalk rivers spanning Wiltshire, Hampshire and Dorset. For this, I examined macroinvertebrate responses to flow regime alterations caused by operations such as groundwater withdrawals and effluent water returns. **This research highlighted that rivers most commonly experienced low-moderate groundwater withdrawal effects, where water volumes were reduced by approximately 10-15%. Such flow regime alterations did not negatively affect macroinvertebrates.** Instead, some declines in ecological health were observed in rare instances that groundwater withdrawals led to high proportional reductions on water volumes (approximately 50% during summer, where flow levels are low and water demands are high), or when flows were artificially elevated by effluent water returns (and potential pollutants associated with this). This research was important in highlighting that the majority of Wessex Water's water resource management operations did not adversely affect macroinvertebrate communities, which has wider implications for guiding ecologically acceptable flow regime alterations.



Flow regime alterations at macroinvertebrate sampling sites examined in White et al (2021; Fig. 3, pp. 3).

Future research

Understanding how water resources can be managed to balance societal and ecosystem demands is a challenge of the 21st century. This is being addressed within different global 'environmental flow' research agendas. This includes 'stream support' strategies implemented along English groundwater-fed rivers, whereby groundwater is inputted directly into watercourses undergoing drought. One key aspect of environmental flows is recognising that "natural" flow regimes are not achievable in many river systems, but instead ecologically relevant hydrological events should be targeted in such situations to improve ecosystem health. The image below provides an example of this by highlight specific parts of a natural flow regime necessary for salmonids, which could be mimicked in unnatural flow regimes.



An annotated 'hydrograph' indicating key natural flow regime elements across the year required for salmonid populations, which could be mimicked in rivers with unnatural flow regimes (adapted from Fig. 2 in Acreman and Ferguson, 2010, pp. 41).

Three key areas that I believe require urgent research attention to help protect river ecosystems from flow regime modifications are:

- *Developing transferrable relationships*: The extent and pace of flow regime alterations has far exceeded our ability to understand their effects across different river ecosystems (Chen and Olden, 2018). As such, reliable models that can reliably extrapolate the ecological effects of flow regime modifications to different environments is integral to guiding river management and restoration practices.
- *Understanding the effects of flow alongside other pressures*: The river flow regime is often coined the 'master variable' (Poff *et al*., 1997) driving river ecosystems as it has direct (e.g. drought causing streambed drying) and indirect (e.g. pollutant dilution, habitat changes) implications for freshwater organisms. Understanding these complicating interactions is fundamental for safeguarding river ecosystems.
- *Climate change:* Climate change is shifting river flow regimes, so what is historically 'natural' is becoming a thing of the past. Understanding these changes in flow regimes alongside rising water demands stemming from human population growth is a key challenge for protecting and restoring river ecosystems (Visser *et al*., 2019)

References / Further reading

A paper summarising environmental flows applied across the United Kingdom:
Acreman, M.C. and Ferguson, A.J.D. (2010). Environmental flows and the European water framework directive. *Freshwater Biology*, 55(1), pp.32-48.

A review paper and one of the first to pioneer the 'natural flow regime':
Poff, N.L., Allan, J.D., Bain, M.B., Karr, J.R., Prestegaard, K.L., Richter, B.D., Sparks, R.E. and Stromberg, J.C. (1997). The natural flow regime. *BioScience*, 47(11), pp.769-784.

A research paper indicating how climate change-driven changes to river flow regimes threaten river ecosystem in southeast England:
Visser, A., Beevers, L. and Patidar, S. (2019). The impact of climate change on hydroecological response in chalk streams. Water, 11(3), p.596.

Highlighted research paper examining how macroinvertebrate communities were affected by different flow regime modifications in southern England:
White, J.C., Fornaroli, R., Hill, M.J., Hannah, D.M., House, A., Colley, I., Perkins, M. and Wood, P.J. (2021). Long-term river invertebrate community responses to groundwater and surface water management operations. *Water Research*, 189, 116651.

Research paper examining how macroinvertebrate communities were affected by groundwater withdrawals within 'chalk winterbournes' in southern England:
White, J.C., House, A., Punchard, N., Hannah, D.M., Wilding, N.A. and Wood, P.J. (2018). Macroinvertebrate community responses to hydrological controls and groundwater abstraction effects across intermittent and perennial headwater streams. *Science of the Total Environment*, 610. 1514-1526.