

WYE FOCUS on phosphorus?

By Dr Shane Rothwell, Dr Kirsty Forber
and Professor Paul Withers,
Lancaster University

The element phosphorus is essential for all life on earth, yet it is unique in that it is naturally rather scarce in the biosphere (Smil 2000). Despite this, it makes up about 60% of our bones and teeth and underpins the very building blocks of DNA and our metabolism.

In natural ecosystems phosphorus is weathered from rocks, and slowly travels through terrestrial and aquatic environments, where after many thousands of years it ends up deposited on the ocean floor to be transformed back into rock many millennia later. Along its journey, phosphorus will cycle many times in plants and animals, being absorbed or eaten and released in excreta or from decaying matter. It can remain in soil for centuries until it is transported by heavy rains, slowly creeping into rivers where it may rest in sediments passing along with currents or being taken up by aquatic plants and algae until it eventually reaches the ocean. It is a long journey that until the advent of the agricultural revolution remained relatively quiet and undisturbed.

The discovery of guano and phosphate rock which could be mined was a game changer for global food production and this apparently endless supply of phosphorus was synthesised into fertilisers to be liberally applied to agricultural land in many regions of the world, boosting yields during the 20th century. Whilst helping to end hunger in some parts of the world, the natural cycle of phosphorus was now broken, accelerated to more than triple the natural rate (Yuan et al 2018) with devastating consequences for our aquatic ecosystems. The low cost of phosphorus fertiliser meant



it was applied in excess of what crops required to build up soil fertility. As livestock production expanded, greater volumes of manures were also being recycled to agricultural land, providing even more phosphorus for crops and grassland. However, the disaggregation, expansion, and intensification of livestock production means we now have localised excesses of manure that are high in phosphorus. Being bulky and difficult to transport, this manure is often applied to land even though arable crops and grassland don't need the phosphorus contained in them, leading to large agricultural phosphorus surpluses accumulating in our soils.

Managing phosphorus in other parts of our food system, in particular that excreted from our growing population and subsequently processed at waste water treatment works, is also critical. Depending where you are, phosphorus lost to rivers may be coming from mostly waste water treatment work discharge or from agricultural sources. It is estimated that globally every year 1.47 million tonnes of phosphorus are released into



freshwater bodies due to human activity, and 38% of freshwater basins receive more phosphorus than they can assimilate (Mekonnen and Hoekstra 2018), causing widespread eutrophication and environmental degradation.

In the UK we rely on imported phosphorus to support our food system. Our analysis indicates we import around 180,000 tonnes of phosphorus into our food system annually, approximately half as fertilisers, but also embedded in food and livestock feed. Only about 43% of this ends up in the food we eat or in exportable 'commodities' and the equivalent of around 15% of our phosphorus imports are ultimately lost from our food system to our fresh and coastal waters, mostly via agriculture and waste water treatment. In England, elevated riverine phosphorus levels are now the biggest cause of failure to meet water quality targets set out in legislation (Environment Agency 2019).

We have therefore reached a crucial moment where we must balance the need for phosphorus

in food production with the protection of our water environment. The RePhoKUs (The Role of Phosphorus in the Resilience and Sustainability of the UK Food System) project, an international project lead from Lancaster University, set out to examine phosphorus use in the UK food system to help transform our current activities, practices and management of phosphorus. We have looked at phosphorus at different spatial scales: UK, regional, and catchment, to understand how phosphorus is used in our food system; to unpick the complexities and variation in response of riverine water quality to anthropogenic phosphorus inputs; and to identify the capacity for food system stakeholders to change their behaviour at each scale. Ultimately this helps identify where change is needed and what can be done to move towards a more efficient, resilient and sustainable food system (Withers et al 2020). This journey has led us to the River Wye where the negative impact of phosphorus on water quality has recently made national headlines and called the local community to action. Recent data published by the ►



The much-publicised algal bloom on the River Wye during the summer of 2020

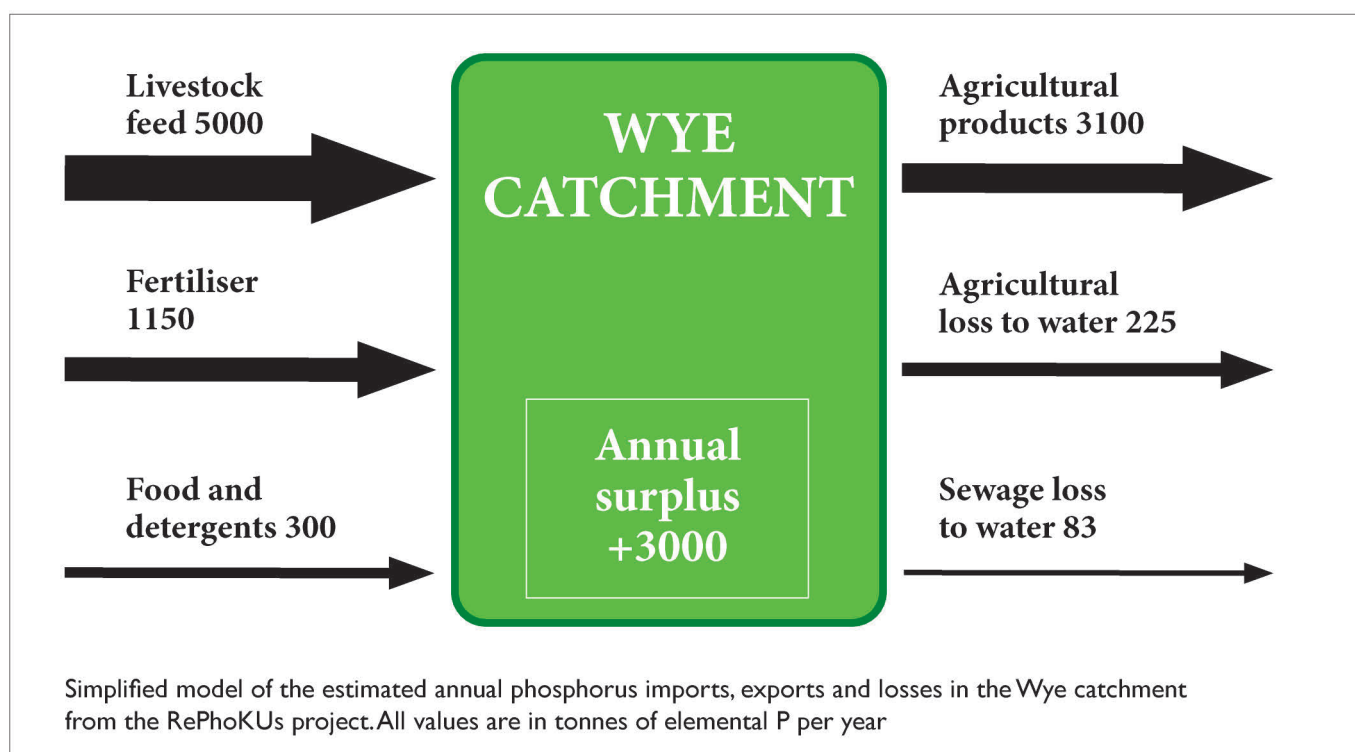
Environment Agency (NRW, EA and NE 2021) suggest that >60% of the phosphorus entering the River Wye is from agricultural sources; this contrasts with many other catchments in the UK where riverine phosphorus pollution is predominantly from wastewater discharges (Neal et al 2010).

Farming in the Wye catchment without contributing ecologically damaging concentrations of phosphorus to the local rivers is very challenging. A combination of factors create the perfect storm for accelerated phosphorus loss along surface and sub-surface hydrological pathways into the river: high annual phosphorus inputs to the landscape; poorly-buffered, silty soils that release high concentrations of dissolved phosphorus into storm runoff; highly dispersible soils that erode easily and make rivers turn red; and steep, runoff-prone slopes and moderate to high rainfall. Our nutrient accounting model has identified that the annual agricultural phosphorus input pressure in the Wye landscape could be nearly three times the national average. This is driven by a large livestock population, in particular poultry, and their manure production. Our analysis shows that the phosphorus contained in the manure produced in the catchment alone exceeds that actually required by the crops and grass by circa 20%, regardless of any fertiliser use. This high overall phosphorus loading on the Wye catchment, combined

with its particularly vulnerable soil and landscape properties, is not sustainable and will create long-term pollution because of the high risk of this phosphorus reaching the river.

We have compiled data from across a number of UK regions and catchments which clearly show that the greater the phosphorus input pressure on a landscape, the greater the loads and concentrations of phosphorus in the rivers. This strongly suggests that if we are to reduce phosphorus pollution in the Wye we must not only continue to reduce land runoff rates, soil erosion risk and direct livestock pollution, but also reduce the agricultural phosphorus surplus generated each year, and in particular the manure phosphorus that is inappropriately spread to land. A goal of a 'catchment zero phosphorus surplus' would be a step in the right direction and facilitate the innovative technologies required to cost-effectively recover 'fertiliser-grade' renewable phosphorus from manures. Renewable fertilisers can then substitute for the fertilisers currently imported into the Wye catchment, and, more importantly, could be transported to other regions of the UK to replace imported non-renewable phosphorus fertiliser.

However, we must go even further in the future. Achieving a zero surplus would not address the phosphorus runoff from soils that have already far more



phosphorus than they need for agricultural production. In many areas with intensive agriculture, soils have unnecessarily high levels of crop-available phosphorus due to the continued build-up of annual phosphorus surpluses over many years (so-called ‘legacy P’). These soils in the Wye represent a particularly high risk of phosphorus loss to water and must be ‘drawn down’ by omitting all phosphorus inputs, both manures and fertilisers, while still being farmed. Our research shows that it is possible to draw down legacy soil P reserves to a more sustainable level of soil fertility without risk to crop yields. However, achieving a catchment zero phosphorus surplus, or encouraging agriculture to draw down legacy phosphorus, requires a level of governance that is beyond the responsibility of the individual farmer or regional industry.

Phosphorus pollution in the River Wye is ultimately a consequence of the multiple sources (sewage and industrial discharges, agricultural runoff and road runoff) of phosphorus reaching the river and reflects wider food system challenges. No one sector is solely to blame and it is a collective stakeholder responsibility to mitigate the problem. We hope the RePhoKUs project has helped provide the evidence base to allow stakeholders to take the innovative actions and management changes required to both reduce the very high phosphorus input pressure, and the risk of

phosphorus loss in land runoff and erosion. The Wye Catchment Partnership, the Wye and Usk Foundation (WUF), Wye Agri-Food Partnership and the Friends of the Wye are examples of the active stakeholder forums that exist to facilitate such change. Investment in higher resolution and targeted routine water quality monitoring programmes is needed to monitor progress, and WUF and citizen science are already helping in this regard. Adoption of more sustainable catchment management is also consistent with a national policy drive towards a more circular nutrient economy that relies on lowering overall phosphorus demand and using renewable phosphorus sources; this is vital to safeguard food and water security in the region well into the future and maintain the high ecological biodiversity and recreation status for which the River Wye is famous. □

Dr Shane Rothwell and Dr Kirsty Forber are both Senior Research Associates on the RePhoKUs project and Prof Paul Withers is the RePhoKUs project lead. To find out more about the project please visit <http://wp.lancs.ac.uk/rephokus/>

References for this article are available on the WTT website: www.wildtrout.org/content/salmo-trutta-article-references