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| **Institution: Queen Mary University of London** | | |
| **Unit of Assessment: 5** | | |
| **Title of case study: Counteracting the Damaging Effects of Fine Sediment Pollution in UK Rivers** | | |
| **Period when the underpinning research was undertaken: 2009 - present** | | |
| **Details of staff conducting the underpinning research from the submitting unit:** | | |
| **Name(s):** | **Role(s) (e.g. job title):** | **Period(s) employed by submitting HEI:** |
| 1) J Iwan Jones | 1) Head of the River Communities Group | 1) 05/2009 - present |
| 2) John F Murphy | 2) Research Officer | 2) 05/2009 - present |
| 3) Amanda Arnold | 3) Research Officer | 3) 01/2011 - present |
| 4) John H Blackburn | 4) Research Officer | 4) 05/2009 - 09/2012 |
| 5) Charles P Duerdoth | 5) Research Assistant | 5) 05/2009 - 08/2017 |
| 6) Adrianna Hawczak | 6) Research Assistant | 6) 05/2009 - 09/2013 |
| 7) James L Pretty | 7) Laboratory Manager | 7) 05/2009 - present |
| **Period when the claimed impact occurred: August 2013 - present** | | |
| **Is this case study continued from a case study submitted in 2014? N** | | |

**1. Summary of the impact** (indicative maximum 100 words)

Soil erosion can lead to fine sediment pollution in rivers, reducing water quality and increasing the risk of severe floods. This degradation costs an estimated GBP1,200,000,000 a year in England and Wales. Researchers at Queen Mary's River Communities Group have developed a novel sensitive biotic index, the Combined Fine Sediment Index (CoFSI), which identifies rivers where fine sediment pollution is a problem and isolates the likely sources, providing the basis for targeted actions to mitigate risks. The new index, used alongside ecological models developed by the Group, has enhanced the river management tool, the River Invertebrate Classification Tool (RICT2), used by the UK's four environmental agencies to monitor water quality through its ecological status. These agencies can now accurately identify hotspots of river pollution, and work with landowners to reduce and mitigate risks, helping the UK to meet its obligations to improve water quality within the EU Water Framework Directive.

**2. Underpinning research** (indicative maximum 500 words)

There are more than 4,000 rivers in the UK, stretching across a catchment area of 240,000 km$^2$. As well as providing an important habitat for wildlife and a space for recreation and wellbeing, the UK's rivers also provide water for domestic and industrial use, fisheries and transport. Importantly, when managed appropriately, they provide a natural defence against flooding and reduce emergency costs during such catastrophic incidents.

Currently, 80% of the UK's rivers are failing to achieve their national water quality targets. Poor water quality can be caused by several environmental factors, but the most common cause is an excess of fine sediment run-off from damaged agricultural land. This foreign sediment clogs the riverbed, killing the invertebrates that live there, as well as the eggs of fish, such as salmon, trout and shad, fisheries important economically and for conservation. Fine sediment water pollution also increases the production of methane and other greenhouse gases through the breakdown of organic matter under anoxic conditions. Currently more than 800 of the UK's rivers (20%) are damaged by excess sediment, with the problem costing an estimated GBP1,200,000,000 a year in England and Wales. These costs come from lost farmland and soil fertility due to erosion, as well as the extensive dredging required to mitigate flood risks.

Queen Mary's River Communities Group, based at the Freshwater Biological Association River Laboratory in Dorset and headed by Dr. Jones, conducts research into the management of freshwaters, the factors causing rivers to fail requisite quality standards, and how to deliver improvements at the national scale. From 2009-2012, the Group, in collaboration with the environmental consultancy ADAS, the University of Southampton and the Centre for Ecology and Hydrology (CEH), undertook a Department of Environment, Food & Rural Affairs (Defra)-

funded research project [3.1]. This project investigated the nature, sources and consequences of pollution from fine sediment in relation to agricultural activity in the UK.

First, the researchers determined the extent to which intensive agriculture pollutes rivers with fine sediment. Historical background rates of soil loss were estimated from the accumulation of sediment in lakes prior to agricultural intensification [3.2], enabling the group to identify the excess sediment load produced from intensive agriculture. They found sediment pollution was widespread: in some places current loads from agriculture are three times higher than standard levels [3.3]. These findings were corroborated by the research team's newly developed identification methods, using stable carbon and nitrogen isotopes and near-infrared reflectance spectra to determine the source of the sediment pollution [3.4]. Commissioned by the Scottish Government, Drs. Jones and Murphy tested the existing methods used by the UK environmental agencies to identify locations where fine sediment pollution is most severe. The researchers found that the existing methods did not work, because they did not consider the natural variation of fine sediment in riverbeds [3.5].

Second, because the existing methods did not adequately identify rivers at risk, Queen Mary's team conducted a nation-wide survey, collecting data on the UK rivers' sediment conditions as well as their macroinvertebrate communities. They observed that species communities change with levels of fine sediment – with the loss of sensitive invertebrate species as fine sediment levels increase. This large scale observation demonstrates the ecological impacts of fine sediment pollution but importantly enabled Jones and co-workers to develop a new biotic index, the Combined Fine Sediment Index (CoFSI) [3.6]. The unique feature of the CoFSI is that it provides a combined assessment of both the inorganic and organic components of fine sediment on invertebrates in rivers. Because these two components differ in both their combined and separate effects (organic sediment can result in oxygen depletion due to enhanced microbial activity), and are likely to come from different sources, the CoFSI enables its user to narrow down the source of a river's fine sediment pollution. The researchers then developed a novel framework that uses CoFSI data and data on catchment land use and management to assess the causes of biological degradation of rivers [3.7]. This approach identified:

- river catchments in England and Wales in need of management to prevent the negative ecological impacts of fine sediment
- the likely sources of fine sediment pollution
- approaches to reduce fine sediment pollution and thus best achieve improved water quality [3.7].

CoFSI is now an essential part of the River Invertebrate Classification Tool (RICT), software used by all four UK environmental agencies to model and determine the ecological status of rivers, in compliance with the EU Water Framework Directive. RICT incorporated CoFSI in 2020.

**3. References to the research** (indicative maximum of six references)

[3.1] Collins, A. L., Jones, J. I., Sear, D. A., Naden, P. S., Skirvin, D., Zhang, Y. S., Gooday, R., Murphy, J., Lee, D., Patterson, I., Foster, I. D. L., Williams, L. J., Arnold, A., Blackburn, J. H., Duerdoth, C. P., Hawczak, A., Pretty, J. L., Hulin, A., Marius, M. S. T., Smallman, D. J., Stringfellow, A., Kemp, P., Naura, M., Brassington, J., Hornby, D. & Hill, C. (2015). *Extending the evidence base on the ecological impacts of fine sediment and developing a framework for targeting mitigation of agricultural sediment losses* (Report No. WQ0128). Defra. http://sciencesearch.defra.gov.uk/Document.aspx?Document=13478_ALC_WQ0128_Evid4_WORDversionforfinaleditshFINALVERSION.pdf

[3.2] Foster, I. D. L., Collins, A. L., Naden, P. S., Sear, D. A., Jones, J. I. & Zhang Y. (2011). The potential for paleolimnology to determine historic sediment delivery to rivers. *Journal of Paleolimnology, 45*, 287-306. https://doi.org/10.1007/s10933-011-9498-9

[3.3] Naden, P. S., Murphy, J. F., Old, G. H., Newman, J., Scarlett, P. M., Harman, M., Duerdoth, C. P., Hawczak, A., Pretty, J. L., Arnold, A., Laize, C., Hornby, D. H., Collins, A. L., Sear, D. A. & Jones, J. I. (2016). Understanding the controls on deposited fine sediment in the streams of

agricultural catchments. *Science of the Total Environment*, *547*, 366-381. https://doi.org/10.1016/j.scitotenv.2015.12.079
[3.4] Collins, A. L., Williams, L. J., Zhang, Y. S., Marius, M., Dungait, J. A. J., Smallman, D. J., Dixon, E. R., Stringfellow, A., Sear, D. A., Jones, J. I. & Naden, P. S. (2013). Catchment source contributions to the sediment-bound organic matter degrading salmonid spawning gravels in a lowland river, southern England. *Science of the Total Environment*, *456-457*, 181-195. https://doi.org/10.1016/j.scitotenv.2013.03.093
[3.5] Davy-Bowker, J., Clarke, R. T., Jones, J. I. & Murphy, J. F. (2014*). River Invertebrate Classification Tool Science Development Project: Describing the impact of abstraction and fine sediment pressures on the biological communities in Scottish rivers* (Report No. S/0011/R). Scottish Government. https://www.fba.org.uk/FBA/Public/Discover-and-Learn/Projects/RIVPACS-Reference-Sites-and-Reports.aspx
[3.6] Murphy, J. F., Jones, J. I., Naden, P. S., Pretty, J. L., Duerdoth, C. P., Hawczak, A., Arnold, A., Blackburn, J. H., Old, G., Sear, D. A., Hornby, D. & Collins, A. L. (2015). Development of a new biotic index of stream macroinvertebrate community response to deposited fine sediment stress. *Freshwater Biology*, *60* (10), 2019-2036. https://doi.org/10.1111/fwb.12627
[3.7] Collins, A. L., Jones, J. I., Sear, D. A., Naden, P. S., Skirvin, D., Zhang, Y. S., Gooday, R., Murphy, J., Lee, D., Patterson, I., Foster, I. D. L., Williams, L. J., Arnold, A., Blackburn, J. H., Duerdoth, C. P., Hawczak, A., Pretty, J. L., Hulin, A., Marius, M. S. T., Smallman, D. J., Stringfellow, A., Kemp, P., Naura, M., Brassington, J., Hornby, D. & Hill, C. (2015). *Using national GIS layers to support spatial targeting of agricultural sediment mitigation measures* (Report No. WQ0182ANX). Defra. (This is an annex to the final report of Defra project WQ0182). http://sciencesearch.defra.gov.uk/Document.aspx?Document=12793_ALC_WQ0128_spatialtargetingwithGISa.pdf

**Evidence of quality of the research:**

[EQR.1] Collins, A. L. (ADAS) [PI] & Jones, J. I. [Co-PI]. (2009-2012). Extending the evidence base on the ecological impacts of fine sediment and developing a framework for targeting mitigation of agricultural sediment losses. [WQ0128]. *Defra*. Research Grant, GBP780,000 (ADAS & Queen Mary combined), GBP248,000 (Queen Mary only).
[EQR.2] Davy-Bowker, J. (FBA) [PI] & Jones, J. I. [Co-PI]. (2012-2013). Describing the impact of abstraction and fine sediment pressures on the biological communities in Scottish rivers. [CR/2013/11]. *The Scottish Government*. Research Grant, GBP34,000.

**4. Details of the impact** (indicative maximum 750 words)

Over 20,000km$^2$ of soil are at risk of erosion in England and Wales and intensive agriculture is the main source of this degradation. The subsequent fine sediment pollution generated is among the most widespread and detrimental forms of diffuse aquatic pollution and as a result, it is a key priority for governments in the UK and internationally to reduce its damaging effects. UK government bodies recognise Jones' tool to assess the health of UK rivers, the CoFSI, and incorporated it into their strategy to mitigate this problem.

**Enhancing UK environmental agencies' tools to identify fine sediment pollution**

Drs. Jones and Murphy demonstrated that the existing methods used by the UK environmental agencies to identify the source of fine sediment pollution were not working [3.1, 3.5]. As a result, the researchers developed a new, more sensitive biotic tool, the CoFSI [3.6]. This index, which relies on the characterisation of macroinvertebrates in freshwater bodies, is now an essential part of the RICT, used by the UK's four environmental agencies (Environment Agency; Scottish Environment Protection Agency; Natural Resources Wales; Northern Ireland Environment Agency) to determine the ecological status of rivers [5.1]. Updated to RICT2 in 2020, RICT2 is the standard against which the environmental agencies compare results to establish whether the legal obligations of health freshwater systems are met.

The inclusion of CoFSI (covering inorganic, organic and combined sediment pressure) into RICT2 [5.2] enables the agencies to determine, for the first time, the extent to which invertebrate communities in rivers are damaged by fine sediment pollution [5.3] and therefore identify the hotspots of habitat degradation. With such information, the environmental agencies are better

placed to work with farmers to manage sediment pollution and mitigate its negative impact on water quality by knowing specifically where the fine sediment has come from.

**Enabling environmental agencies to take action to mitigate pollution**
All of the UK's environmental agencies use RICT2 to classify the ecological quality of rivers, in accordance with the EU's Water Framework Directive [5.3]. This enhanced version, incorporating the CoFSI developed by Jones [5.2], now monitors water quality across the UK more precisely [5.1]. These environmental agencies monitor more than 15,000 water bodies, including rivers, lakes and canals every three years (with at least two samples taken in the sample year). When they identify a failure in water quality, the CoFSI is used to reveal if the failure is caused by fine sediment pollution. If it is, a programme of measures is then triggered to address the causes of the fine sediment pollution. The environment agencies have the power to encourage or enforce changes in behaviour through either advisors (eg Catchment Sensitive Farming) or fines respectively, affecting landowners, businesses and farmers across the entire river catchment.

In the current three-year cycle, a total of 810 water bodies in England and Wales failed to meet the quality standard required because of sediment pollution [5.4]. The National Ecology Advisor, Environment Agency, explains the value of the new index: "The CoFSI index has helped the Agency to identify where fine sediment is causing an impact on rivers and helps us manage these risks. The ability to detect the impact of the organic component of fine sediment has been of particular importance as this was something we lacked in our arsenal of tools for managing pressures on rivers. Where sites fail to achieve 'Good' status or better, a programme of measures is put into place to reduce those factors causing failure" [5.3]. The agency has taken "advantage of the unique ability of CoFSI to separate the effects of the organic component of sediment from the physical effects" [5.3] and proceeded to conduct investigations into agricultural activities they previously had not been able to do.

**Protecting England's most valuable habitats: supporting Natura 2000 sites**
The European Natura 2000 sites form the world's largest network of protected areas for nature conservation, protecting Europe's most valuable and threatened species and habitats. In England there are 338 Natura sites, including Sites of Special Scientific Interest and Special Areas of Conservation, which together covers more than 20,000km$^2$ of terrestrial and marine locations. These sites are critical to reverse the decline of biodiversity. Jones' research on sediment sources and their varying effects has informed and guided Natural England, the Environment Agency, and other key partners (eg Catchment Sensitive Farming) in developing the Diffuse Pollution Theme Plan in 2015 and the continued development and implementation of individual Diffuse Water Pollution Plans for target catchments, protecting England's Natura 2000 sites. By linking catchment land use and management to biological impacts, these organisations can plan how, where and when landowners should adopt practices that ameliorate the effect of fine sediment pollution on these sites, and advise farmers accordingly [5.5]. The changes in management practice are applied through the Higher Level Countryside Stewardship scheme with the aim to improve the existing regulatory framework and adopt incentive-based measures when working with catchment owners [5.6].

**5. Sources to corroborate the impact** (indicative maximum of 10 references)

[5.1] *River Invertebrate Classification Tool (RICT)*. Freshwater Biological Association. https://www.fba.org.uk/FBA/Public/Discover-and-Learn/Projects/RICT%20Application.aspx Accessed 07 January 2021
[5.2] Murray-Bligh, J. (2020, 09 April). An introduction to the new RICT2 software. *Environmental Agency*. https://www.fba.org.uk/common/Uploaded%20files/RICT2%20Introduction%20v4.pdf
[5.3] J. Murray-Bligh. National Ecology Advisor. *Environment Agency*. (testimonial letter, 16 July, 2019). [Corroborator 1]
[5.4] *WFD Catchment Management Information England - Reasons for Failure*. Find open data - UK Government. https://data.gov.uk/dataset/0a3a46d8-8492-47e7-8e27-7cc33709873c/wfd-catchment-management-information-england-reasons-for-failure Accessed 07 January 2021

[5.5] Natural England. (2015). *Application of the cross sector pollutant source apportionment modelling framework to protected sites: Covers multiple Natura 2000 sites*. http://publications.naturalengland.org.uk/file/4894567586332672
[5.6] Natural England. (2015). *Diffuse water pollution theme plan: Developing a strategic approach to diffuse water pollution for England's Natura 2000 sites*. http://publications.naturalengland.org.uk/file/5645420019580928