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Sediment dynamics in an upland temperate catchment: changing sediment sources, rates and deposition.

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Robust identification of catchment suspended sediment sources is a prerequisite both for understanding sediment delivery processes and targeting of effective mitigation measures. Fine sediment delivery can pose universal management problems, especially with regard to nutrient run-off and lake siltation. In this study, we magnetically fingerprinted monthly collections of suspended sediments from the three main tributaries to Bassenthwaite Lake, Cumbria, UK and compared these to material within the lake. Ferrimagnetic grain size and magnetic 'hardness' vary significantly between the suspended sediments collected from the different tributaries, with the 8-31 μm and 31-63 μm clastic grain fractions displaying greatest magnetic contrasts. Post-depositional formation of bacterial magnetosomes is evident in the $2 - 8$ μm and < 2 μm fractions of the lake sediments. As magnetic properties are strongly particle size dependant, we used only the detrital, clastic fractions, 8-31 μm and 31-63 μm for comparison with the potential source suspended sediments. Dating and analysis of the sedimentary records of four one meter cores from Bassenthwaite identifies variable sedimentation rates across the deep lake basin. Mineral magnetic techniques, supported by independent geochemical analyses, identify significant variations both in sediment source and flux over the last $\sim$ 2500 years. Using a quantitative fuzzy clustering technique, we show that between $\sim$2500 years BP and $\sim$1700 AD sediment fluxes to the lake were low and dominated by material sourced from within the River Derwent sub-catchment (providing 80% of the hydraulic load at the present day). Post-1700 AD, the lake sediments became dominantly sourced from Newlands Beck (presently providing $\sim$10% of the lake's hydraulic load). Three successive, major pulses of erosion and increased

sediment flux appear linked to specific activities within the catchment, specifically; mining activities and associated deforestation in the mid – late 19^{th} century, agricultural intensification in the mid- 20^{th} century and, within the last decade, the additional impact of climate change. We also discuss a longer 3m record spanning $\sim$6000 years aiding evaluation of the longer term natural variability within the lake. We find that despite significant land-use change from $\sim$3,500BP (evident from the pollen record) the catchment has been able to 'buffer' or 'absorb' such pressures (particularly increased sediment delivery) up until the last few hundred years. Thus with novel application of magnetic parameters we have shown greatest rates of change in the most recent period to result from exceedance of natural buffering systems, which resulted in increased sediment delivery and their associated environmental problems. These results are important for all upland areas as modifications in climate are progressively superimposed upon the effects of previous and/or ongoing anthropogenic catchment disturbance.