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What makes a fish happy?: The identification of land use hotspots using inverse modeling of fish data

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Research has demonstrated that landscape or watershed scale processes can influence instream aquatic ecosystems, in terms of the impacts of delivery of fine sediment, solutes and organic matter (e.g. Allan and Johnson, 1997; Harding et al., 1998; Hunsaker and Levine, 1995; Dodd and Oakes, 2006; Johnson et al., 1997; Thompson et al., 2000). Testing such impacts upon whole organism populations (i.e. at the catchment scale) has not proven straightforward (e.g. Johnson and Gage, 1997; Pess et al., 2002) and differences have emerged in the conclusions reached. This is: (1) partly because different studies have focused upon different scales of enquiry (Allan et al., 1997; Lammert and Allan, 1999; Stauffer et al., 2000; Wang et al., 1997); but also (2) because the emphasis upon upstream land use has rarely addressed the extent to which such land uses are hydrologically-connected, and hence able to deliver, to the drainage network (Meador and Goldsmith, 2002). However, there is a third issue. In order to develop suitable hydrological models, we need to conceptualise the process cascade. To do this, we need to know what matters to the organism being impacted upon by the hydrological system, such that we can identify which processes need to be modelled. Acquiring such knowledge is not easy, especially for organisms like fish that might occupy very different locations in the river over relatively short periods of time, and where. However, and inevitably, hydrological modellers have started by building up piecemeal the aspects of the problem that we think matter to fish, unable to ask them, exactly, what makes them happy. In this paper, we take a different approach. Rather than defining our models by what we can model, we simplify a distributed model of diffuse pollution delivery down to the very minimum, and then use spatially-distributed ecological data to infer the processes and the associated process parameters

that matter. This inverse modelling allows organisms ‘to speak back’, to tell us what matters, in terms of process representation and model structure. Here, we apply the model to spatially-distributed salmon and fry data from the River Eden, Cumbria. The analysis shows, quite surprisingly, that arable land uses are relatively unimportant as drivers of fry population degradation. What matters most is intensive pasture, a land use that could be associated with a number of negative salmonid fry impacts (e.g. pesticides, fine sediment) and which allows us to identify a series of risky field locations, where this land use is readily connected to the river system by overland flow. Such locations become ‘hotspots’ in which ecological data (or it could be at-a-point water quality data) tell us which land uses they are not happy with and where.