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# A multi-scalar approach for modelling river channel change in the Anthropocene

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Adjustments in river channel morphology during the 'Anthropocene' arise as a cumulative impact from the influence of numerous natural and human stressors operating at multiple spatial and temporal scales. However, the research requirement for data on impacts at multiple scales, and at sufficiently high spatial and temporal resolution to determine reach-level effect, largely prevented such studies until recent improvements in digital technologies and data availability. A meta-analysis of recent cumulative impact studies indicates that the analytical component is still overwhelmingly interpretative, with cause-and-effect reasoning based largely on temporal synchronicity and spatial proximity, whereas our conceptual understanding of adjustment processes is far more nuanced. We propose, instead, that studies of cumulative impact should be underpinned by an analytical model of cause and effect, partly to test and enhance our predictive capabilities and allow scenario setting, but also to learn about the relative sensitivities involved in different parts of the model and thus to prioritize future research endeavours. Our requirements are that the model should be inherently designed to detect reach-level changes over Anthropocene timescales, be capable of integrating co-existing and hierarchical human and natural pressures on fluvial systems, be able to accommodate time-lagged effects and upstream-downstream connectivity, and be based on an explicit conceptual model that can be refined as our process understanding improves.

Bayesian Belief Networks (BBNs) offer some potential in this regard and are becoming an increasingly popular option for dealing with complex, multi-scalar relationships in ecology and other environmental sciences. BBNs consist of a conceptual model of nodes and edges (i.e., graph theory) that qualitatively describe the structure of causal relationships between chains of variables, and a quantitative expression of the relative strength of the hypothesized relationships, described by probability distributions. BBNs offer the flexibility of incorporating different variables taken at various scales from within the catchment (thus accommodating geographical and historical differences in climate and human occupation), can be implemented even when there is some missing data, and can be rapidly optimised to improve data fit by modifying individual parts of the internal probability distributions. They are particularly well-suited to hierarchical cause and effect structuring because data uncertainties are inherently 'internalised' in the development of the model's structure, thus potentially mediating the overall error in a complex chain of relationships. We detail tests in progress to develop models for channel width and depth changes for the main stem of the Santa Clara River, which drains a 4,200 km$^2$ catchment in coastal Southern California.