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Application of hierarchical Bayesian unmixing models in river sediment source apportionment

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Fingerprinting and unmixing concepts are used widely across environmental disciplines for forensic evaluation of pollutant sources. In aquatic and marine systems, this includes tracking the source of organic and inorganic pollutants in water and linking problem sediment to soil erosion and land use sources. It is, however, the particular complexity of ecological systems that has driven creation of the most sophisticated mixing models, primarily to (i) evaluate diet composition in complex ecological food webs, (ii) inform population structure and (iii) explore animal movement. In the context of the new hierarchical Bayesian unmixing model, MIXSIAR, developed to characterise intra-population niche variation in ecological systems, we evaluate the linkage between ecological 'prey' and 'consumer' concepts and river basin sediment 'source' and sediment 'mixtures' to exemplify the value of ecological modelling tools to river basin science.

Recent studies have outlined advantages presented by Bayesian unmixing approaches in handling complex source and mixture datasets while dealing appropriately with uncertainty in parameter probability distributions. MixSIAR is unique in that it allows individual fixed and random effects associated with mixture hierarchy, i.e. factors that might exert an influence on model outcome for mixture groups, to be explored within the source-receptor framework. This offers new and powerful ways of interpreting river basin apportionment data.

In this contribution, key components of the model are evaluated in the context of common experimental designs for sediment fingerprinting studies namely simple, nested and distributed catchment sampling programmes. Illustrative examples using geochemical and compound specific stable isotope datasets are presented and used to discuss best practice with specific attention to (1) the tracer selection process, (2) incorporation of fixed effects relating to sample timeframe and sediment type in the modelling process, (3) deriving and using informative priors in sediment fingerprinting context and (4) transparency of the process and replication of model results by other users.