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Linking catchment and in-stream processes for an integrated simulation of freshwater biota

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Natural catchments, streams and aquatic diversity are globally degraded due to the impacts of industrial and urban development, as well as the intensification of agriculture. Degradation occurres at different spatial scales and rehabilitation measures are required in both streams and catchments, to improve conditions for the aquatic biota. Models, applied for planning restoration measures, are mostly targeting individual components of the complex chain linking the abiotic and biotic environment; e.g., models might be used just for predicting hydrological or hydraulic variables. Hereby, the cause-effect chain is compromised, which links drivers, pressures, state and impacts of the riverine system.

We describe the design of an integrated, GIS-based model system considering the cause-effect chain from the catchment to the stream and aquatic biota. The models require data on climatic and physical catchment properties, and on the geometry and structure of the streams. This enables the assessment of the impact of global change as well as of more regional and local changes on the stream ecosystem on different scales. The approach is based on the Driver-Pressure-State-Impact-(Response) concept and includes the linkage of one ecohydrologic, two hydraulic and two habitat models:

The ecohydrologic model SWAT was used for depicting the discharge regime and ero-sion processes controlled by land use and climate on the catchment scale. The discharge and sediment time series resulting from the hydrologic modelling were used for hydraulic simulations on the reach scale. Water depth, flow velocity, substrate changes and sediment transport were simulated in variable resolutions with the hydraulic models HEC-RAS one-dimensionally and with AdH two-dimensionally.

Combined with structural river mapping, the temporally and spatially dynamic results of the hydraulic models were used for describing macroinvertebrate habitats. Two independent simulations were carried out: First, the distribution of the freshwater clam Sphaerium corneum was modelled with the species distribution model BIOMOD, based on parameters related to hydraulics and sediment transport. Second, the Habitat Evaluation Tool (HET) was developed. HET was used to simulate the prevailing macroinvertebrate community in the stream based on the river's substrates.

Model results are maps and statistics of the spatial occurrence of species at different points in time which are connected to the prevailing environmental conditions. Results of the submodels show very good agreement with observed hydrological and hydraulic parameters and good agreement with observed spatio-temporal erosion. Simulated spatial species distributions are realistic when compared to observed distributions.

The developed model system advances integrated modelling, but future improvements are necessary. This particularly concerns the simulation of abiotic parameters, investigation of organism preferences, the combined simulation of numerous organism groups and the simulation of interactions and feedback loops.