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Modeling macroroughness contribution to stream ecosystem functioning

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Changing the natural flow regimes, such as caused by anthropic water uses or climate change, causes environmental degradation in streams. Good understanding of this environmental degradation is of vital importance to minimize cascading effects on stream ecosystem functioning. Quantifying the environmental impact of altering the natural flow regime on the riverine ecosystem still remains controversial. Environmental indicators are typically used to assess the extent of the disturbance in the stream ecosystem. In this study, we aim to define environmental indicators based on macroroughness contribution to the riverine ecosystem. The effect of the latter is to generate a wake region where the incoming flow velocity decreases and the level of turbulence intensity increases. Fishes minimize energy expenditure by resting in these refuge zones and can easily move to adjacent patches for foraging. Also, streams exchange oxygen with the atmosphere through the free surface. The flux of oxygen getting into the streams strongly depends on the turbulence level, especially the top 10 percent of the water column near the free surface. Partially submerged macroroughnesses perturb the free surface and therefore substantially enhance the level of turbulence at the free surface level. This would increase the reaeration of the streams. We develop an analytical solution for the wake area behind the macroroughness elements. As mentioned, these wake areas represent the regions with high mixing rates and therefore determine the level of oxygenation rate. We apply the model to a case study located in the center of Switzerland in the Aare river. We characterize the statistical distribution of stones diameter by taking orthorectified aerial photographs with drones and analysing them with image processing techniques. Furthermore, we use the gas tracer technique and perform multiple Argon releases to derive the oxygenation rate as a function of the stream discharge. Our results show that the turbulence level and consequently the oxygenation rate increases as the flow discharge increases up to a flow rate. Then, the oxygenation rate has a declining trend with the increasing discharge as some macroroughnesses start to submerge and therefore do not contribute to the wake areas.