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Classifying terrestrial surface water systems using integrated residence time

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Linkages between ecology and hydrology in terrestrial surface water often invoke a discussion of lentic (reservoir) vs. lotic (riverine) system behaviors. However, the literature shows a wide range of thresholds separating lentic/lotic regimes and little agreement on a quantitative, repeatable classification metric that can be broadly and reliably applied across a range of systems hosting various flow regimes and suspended/benthic taxa. We propose an integrated Residence Time (iTR) metric as part of a new Freshwater Continuum Classification (FCC) to address this issue. The iTR is computed as the transit time of a water parcel across a system given observed temporal variations in discharge and volume, which creates a temporally-varying metric applicable across a defined system length. This approach avoids problems associated with instantaneous residence times or average residence times that can lead to misleading characterizations in seasonally- or episodically-dynamic systems. The iTR can be directly related to critical flow thresholds and timescales of ecology (e.g., zooplankton growth). The FCC approach considers lentic and lotic to be opposing end-members of a classification continuum and also defines intermediate regimes that blur the line between the two ends of the spectrum due to more complex hydrological system dynamics. We also discover the potential for “oscillic” behavior, where a system switches between lentic and lotic classifications either episodically or regularly (e.g., seasonally). Oscillic behavior is difficult to diagnose with prior lentic/lotic classification schemes, but can be readily identified using iTR. The FCC approach was used to analyze 15 tidally-influenced river segments along the Texas (USA) coast of the Gulf of Mexico. The results agreed with lentic/lotic designations using prior approaches, but also identified more nuanced intermediate and oscillic regimes. Within this set of systems, the oscillic nature of some of the river reaches was due to flash floods that temporarily turned the primarily lentic stream reaches into lotic systems (not dominantly due to tidal influences). Because the FCC approach is based on system volume and flow characteristics, it is broadly applicable across an entire river reach, pond, or reservoir volume, and so may provide a useful and quantitative common reference point for hydrological and ecological studies going forward. [This work was supported in part by the United States National Science Foundation under grant number 1417433.]