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Coupling C-Q and Lorenz Inequality Analyses to Create a Temporal Targeting Framework for Watershed-Scale Decision-Making

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Degradation of aquatic ecosystem health due to the presence of excess nutrients and sediments is a long-standing, leading global environmental concern. Concentration-discharge (C-Q) relationships have been used to disentangle the hydrologic and biogeochemical drivers affecting the transport dynamics of nutrients, sediments, and other constituents of interest. However, C-Q relationships alone are insufficient to provide actionable information to watershed managers and decision-makers. Rather, a comprehensive understanding of the degree of inequality of pollutant transport over time and space is necessary so that appropriate best management practices can be implemented in the "right place" that is effective at reducing targeted pollutants at the "right time". Such spatial and temporal targeting requires a uniform metric for identifying "hot spots" and "hot moments". Nutrient and sediment transport are known to exhibit strong spatial and temporal inequality, with a small percentage of locations and events contributing to the vast majority of total annual loads. The processes for determining how to reduce total annual loads at a watershed scale often target spatial, but not temporal, components of inequality, such that "hot moments" are far less understood than "hot spots". Here, we introduce a framework using Lorenz Inequality and the corresponding Gini Coefficient to quantify the temporal inequality of nutrient and sediment transport across the Chesapeake Bay watershed and couple the inequality analysis with C-Q analysis to disentangle the relative role of hydrologic versus biogeochemical controls on nutrient cycling and transport and categorize nutrient transport across a response gradient. This framework allows for interpretation of the physical factors that influence the extent to which hydrologic and biogeochemical drivers are attenuated or exacerbated, such that a catchment's ability or lack thereof to buffer highly variable hydrologic and biogeochemical signals can be quantified and understood through the proposed framework.

Data were obtained for 108 sites in the Chesapeake Bay's Non-Tidal Network from 2010 through 2018. The Lorenz Inequality and Gini Coefficient analyses were conducted using daily-scale data for flow and loads of total nitrogen (TN), total phosphorus (TP), and total suspended sediment (TSS) at each gauging station. We leverage these results to create a "temporal targeting

framework" that identifies periods of time and corresponding flow conditions that must be targeted to achieve desired or mandated load reduction goals across the watershed. Among the 108 sites, the degree of temporal inequality for TP and TSS (0.37 – 0.98) was much greater than for flow and TN (0.29 – 0.77), likely due to the importance of overland versus baseflow in the transport pathways of the respective constituents. These findings stress the importance of informed design and implementation of best management practices effective in "hot moments," and not just "hot spots," across impaired watersheds to achieve and maintain water quality restoration goals. The "temporal targeting framework" provides a useful and convenient method for watershed planners to create low- and high-flow load targeting tables specific to a watershed and constituent.