Hydrologic and Biogeochemical Controls on Phosphorus Export from Western Lake Erie Tributaries

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Water quality in Lake Erie (Figure 1) has made national and international headlines in recent years due to the extent and severity of harmful algal blooms (HABs). The formation of HABs in receiving water bodies has been linked to, among other factors, temporal fluctuations in nutrient loadings from their contributing drainage areas. Understanding the dominant processes controlling nutrient loading from intensively managed agricultural watersheds is therefore critical for predicting and mitigating associated adverse environmental impacts.

In this study, the watershed is conceptualized as a nonlinear, hierarchical filter, which transforms input signals from natural and anthropogenic external drivers to produce patterns in observed hydrographs, chemographs, and nutrient loads. Using this approach, we evaluate hydrologic and biogeochemical time series records (1975-2014) from the Maumee and Sandusky watersheds located in northwestern Ohio, USA, to identify the dominant processes controlling phosphorus (P) loadings. These watersheds are both intensively managed agricultural catchments where natural forest and wetland ecosystems have been almost entirely converted to agricultural production, and the hydrology has been significantly modified due to artificial drainage. The Maumee and Sandusky Rivers have experienced substantial shifts in P concentration and load over the past 40 years warranting investigation into past watershed loading patterns. Understanding past watershed P loading patterns will ultimately help improve predictions of future watershed response.

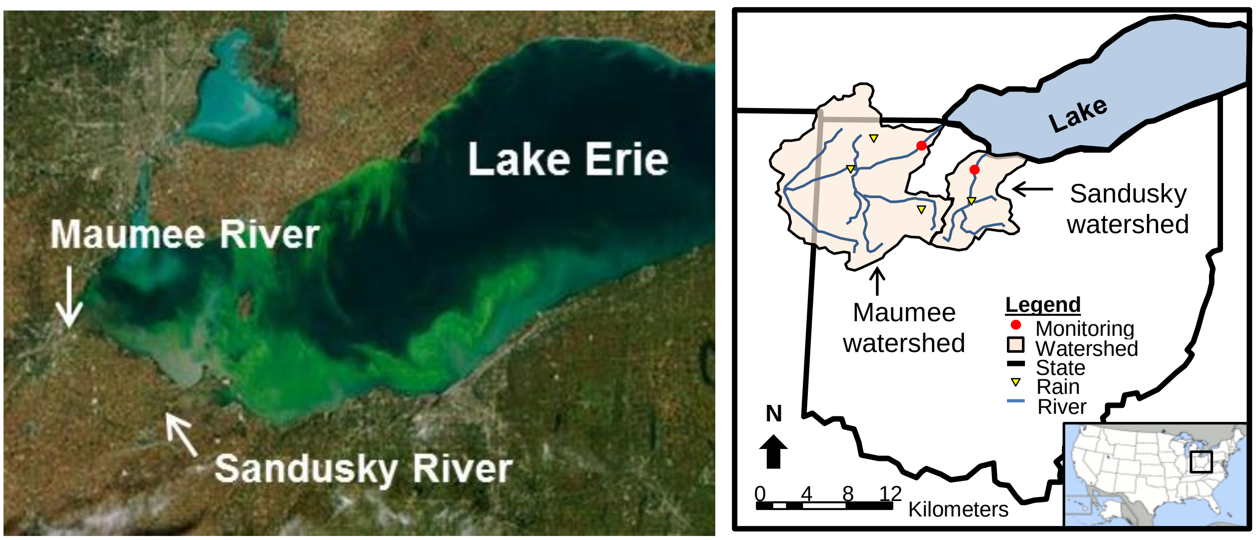

Figure 1. Satellite view of a Lake Erie algal bloom (left) and the location of the Maumee and Sandusky Rivers in northwest Ohio (right).

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Findings indicate that hydrologic processes in these watersheds controlled P loading patterns, as P export was transport-limited (i.e., P loading was strongly correlated to watershed discharge), and P concentrations exhibited chemostatic behavior (i.e., low variability in concentration relative to discharge). The nature and behavior of observed P transport likely stems from a large, ubiquitous source of P present within each watershed as results were similar to those reported for geogenic constituents. Over the 40-year record, analyses showed that the magnitude of the P source has remained relatively unchanged indicating that biogeochemical processes also play a key role in determining P availability. Future P loading in the Maumee and Sandusky watersheds should be expected to continue to be proportional to water flux and current P management strategies may need to be reevaluated to better balance agricultural P requirements and watershed P loadings. Findings from this study not only have implications for nutrient management in the environmentally relevant study watersheds, but also in other intensively managed watersheds across the world.

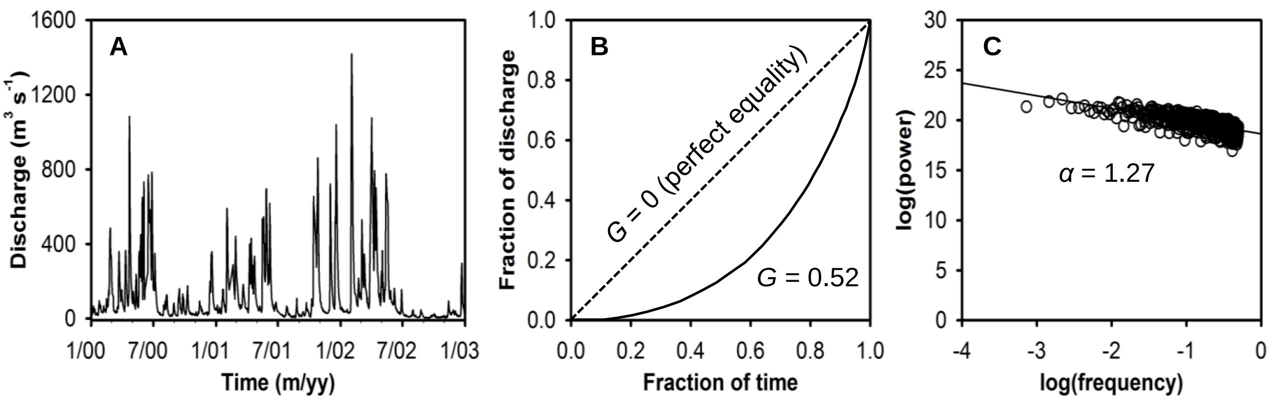

Figure 2. Lorenz curves (B) and spectral density plots (C) were calculated for three year intervals in each watershed over the entire period of record. Discharge time series (A) from the Maumee River (2000-2002) shown as an example.