Limnol. Oceanogr., 52(2), 2007, 856–861

How climate controls the flux of nitrogen by the Mississippi River and the development of hypoxia in the Gulf of Mexico

Simon D. Donner and Donald Scavia

Web Appendix 1. The precipitation-flux relationship.

Dissolved nutrient concentrations in streams and rivers typically exhibit hysteresis: there is a positive correlation between concentration and discharge, but the correlation becomes negative at higher discharge values (e.g., Whitfield and Schreier 1981). During storms or wet periods, concentrations increase on the rising limb of the hydrograph because of flushing of high-concentration waters that accumulated during dry periods (Webb and Walling 1985; McDiffett et al. 1989). At very high discharges, concentration begins to decrease with discharge because of limits to soil N availability. The three expected modes of the relationship between runoff or discharge (Q) and nitrogen concentration (C) or flux ($N = C \times Q$) can be summarized:

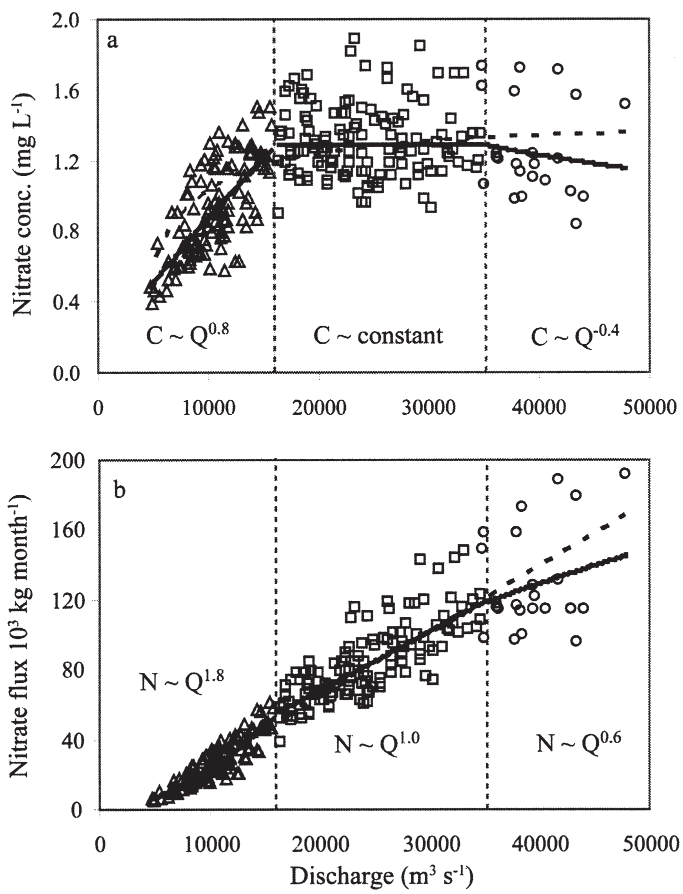

Fig. A1.1. Observed monthly (a) NO_x concentration, C (in mg L^{-1}), and (b) NO_x flux, N (kg $month^{-1}$) versus river discharge (m^3 s^{-1}) for the Mississippi River at St. Francisville, Louisiana, from 1980 to 2000. The relationship between C (N) and discharge for each range of discharge (solid line) and the full range of discharge (dashed line) is displayed.

i) At low Q (baseflow conditions): $C \sim Q$, $N \sim Q^2$
ii) At high Q: $C \sim$ constant, $N \sim Q$.
iii) At very high Q (flood conditions): $C \sim Q^{-a}$, $N \sim Q^{1-a}$, where $0 < a < 1$. The concentration should decrease with Q because soil nitrogen becomes limiting.

We tested the hysteresis theory using monthly data for nitrate concentration, nitrate flux, and river discharge for the Mississippi River at St. Francisville from 1980 to 2002. The relationship between C, N, and Q roughly reflects the three modes (Fig. A1.1):

i) At $Q < 16{,}000$ m^3 s^{-1}: $C \sim Q^{0.8}$ ($r^2 = 0.54$) and $N \sim Q^{1.8}$ ($r^2 = 0.85$)
ii) At 16,000 m^3 $s^{-1} < Q < 34{,}000$ m^3 s^{-1}: $C \neq Q$ and $N \sim Q^{1.0}$ ($r^2 = 0.71$).
iii) At $Q > 34{,}000$ m^3 s^{-1}: $C \sim Q^{-0.4}$ and $N \sim Q^{0.6}$ although neither relationship is statistically significant.

Over the full range of discharge, the concentration–discharge relationship is best described ($r^2 = 0.49$) by a polynomial expression and the flux–discharge relationship is best described ($r^2 = 0.88$) by a linear expression (Fig. A1.1). Similar relationships were also detected using data for every second month, indicating that autocorrelation in the individual time series is not influencing the regression. The fit between the predicted and the observed flux using the linear expression is only marginally different from the fit between the predicted flux and the observed flux using the best fit for the three modes, or only the first two modes ($r^2 = 0.88$). This approximation helps explain the strong linear fit between precipitation or discharge and nitrogen or nitrate flux described in this and other studies (e.g., Donner et al. 2002).

References

Donner, S. D., M. T. Coe, J. D. Lenters, T. E. Twine, and J. A. Foley. 2002. Modeling the impact of hydrological changes on nitrate transport in the Mississippi River Basin from 1955–1994. Glob. Biogeochem. Cycles **16**, doi: 10.1029/2001GB00139.

McDiffett, W. F., A. W. Beidler, T. F. Dominick, and K. D. McCrea. 1989. Nutrient concentration-stream discharge relationships during storm events in a first order stream. Hydrobiologia **179**: 91–102.

Webb, B. W., and D. E. Walling. 1985. Nitrate behavior in streamflow from a grassland catchment in Devon, UK. Water Res. **19**: 1005–1016.

Whitfield, P. H., and H. Schreier. 1981. Hysteresis in relationships between discharge and water chemistry in the Fraser River Basin, British Columbia. Limnol. Oceanogr. **26**: 1179–1182.