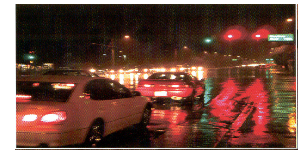
Stoichiometry and Load of Nutrients Exported from Hydrologic Catchments by Storms



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We study the transport of nutrients in runoff from storms. Storms move materials and trigger biogeochemical processes in many ecosystems, but little is known about their role in cities. Especially in arid cities, nutrients accumulate on the landscape during protracted dry periods. Storms mobilize these materials and integrate them in runoff. In cities, the large proportion of impermeable surfaces exacerbates this mobilization.

As a molecule moves through a catchment or fluvial ecosystem, generally along the course dictated by gravity, its progress may be substantially slowed or hastened by various features of the landscape. In a river, for example, a molecule of nitrate may be transported downstream by flowing river water and upstream in the body of a fish. Alternatively, it may be tied up in a leaf on a riparian tree or in the stagnant pool behind a beaver dam.

The retention and transport of nutrients influence several other ecological patterns and processes. These may include productivity, the breakdown of organic matter, the tissue chemistry of biota, the distribution and species composition of ecological communities, and suitability of land and water bodies for human activities. These features of ecological systems will be influenced not only by the amount, but also by the ratios, of critical nutrients.

We thus study coupled nutrient budgets. That is, we examine the mechanisms responsible for retaining and transporting several different nutrients, such as C, N, and P, in tandem. In particular, we are examining the potential for nutrient transport by storms in arid cities.

Our objective was thus to determine what features of storms influenced the amount and ratios of nutrients exported in runoff.

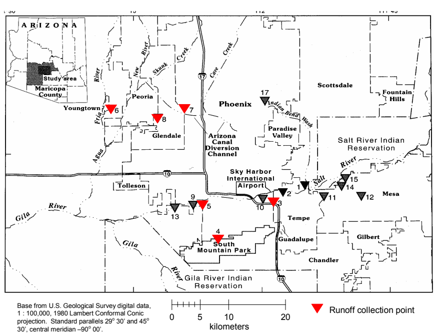

Figure 1. Study area and location of runoff collection points. We obtained storm water runoff data from six locations.

We obtained chemistry and hydrology data from storm water runoff collected at six locations (Fig. 1). These locations marked the output of delineated, urban catchments. Data derive from storms occurring during the period 1991-1998. On some days, runoff was collected from multiple locations. We thus have 108 location x event combinations. We refer to each one of these as an independent "storm." Sample size is less than 108 for all analyses, as incomplete data were collected for some storms.

We analyzed the nutrient chemistry of runoff water as a function of characteristics of the storms.

Storm characteristics included:

- **total precipitation**
- **precipitation intensity (cm / 5 min.)**
- **duration**
- **number of dry days prior to storm**
- **when storm occurred**
  - **year**
  - **monsoon vs. winter cold front**

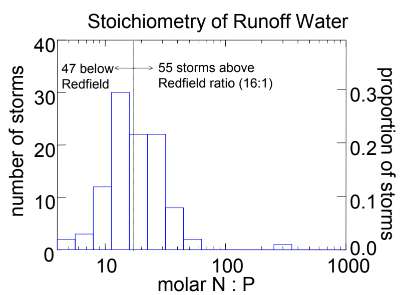

Figure 2. Frequency distribution of the molar nitrogen : phosphorus ratio. These data are of total N and total P (inorganic + recoverable organic forms) from unfiltered water samples. For each storm, we multiplied mean nutrient concentration (mass per volume) by total volume of runoff during storm to obtain load (i.e., mass of N and P exported by storm). These were converted to molar equivalents, and their ratio determined.

Variation in molar N:P ratios (Fig. 2) was not explained by any attributes of storms (Fig. 3). In select cases, however, loads of individual nutrients did correlate with storm features (Fig. 4).

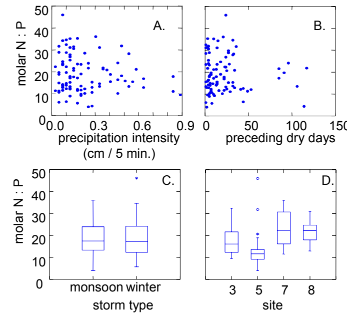

Figure 3. Relationship between molar N:P ratios in storm runoff and select features of storms. N = 91 in panel A, and N = 93 in the other panels. The only statistically significant result, which is depicted in panel D, is that N:P is greater at sites 7 and 8 than at site 5. We have not yet determined a mechanism for this difference.

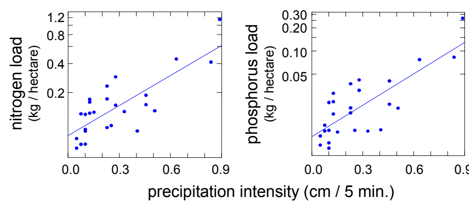

Figure 4. Relationship between nutrient load and precipitation intensity (in both panels, N = 26 storms, $R^2 = 0.6$, and $p < 0.001$). Data derive from site 3, indicated in figure 1. That site samples a catchment of light industrial land use with 80% impervious cover. Site 8, with residential land use and 60% impervious cover, exhibited a similar pattern. At both sites, individual N species (e.g., NO_3, NH_4^+, organic N) also correlated with precipitation intensity. At sites 5 and 7, no forms of N or P were correlated with any features of storms. Data were insufficient to conduct these analyses at sites 4 and 6.

Conclusions

Nutrient chemistry in storm runoff exhibits a great deal of temporal variability. This variation does not reflect inter-annual changes and it does not correspond with seasons.

No features of storms explained variation in N : P ratios. Inputs to a catchment between storms may be required to explain variation of in the stoichiometry of water exported during storms.

Loads of nutrients exported during storms were correlated with storm characteristics. The strongest correlate was rainfall intensity.

Future Plans

coupled nutrient dynamics in catchments comprised by the CAP region

✓ Loads of metals and inorganic minerals (e.g., calcium). Though not fully examined, preliminary analyses suggest that they are also influenced by storm characteristics (Figs. 5 and 6).

✓Spatial perspective. Owing to novel patch types and structure, cities are laboratories for studying basic ideas about spatial pattern and process. We will study nutrient retention and processing within patches and across their edges. Catchments, as our study unit, permits research at different scales and across landscape gradients.

- ❖ multiple scales – nested catchments
- ❖ landscape gradients – contributory catchments into fluvial systems (e.g., Cave Creek, Indian Bend Wash) that traverse the urban-rural gradient (Fig. 7).
- ❖ spatial variation – compare sites of different land use

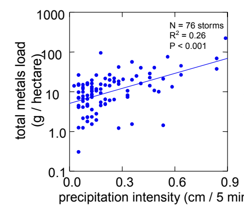

Figure 5. Loads of total metals in storm water runoff as a function of storm intensity. Metals are from unfiltered samples. Total metals is the sum of arsenic, cadmium chromium, copper, lead, nickel, and zinc. Data are from all sites combined. In most cases, individual metals at individual sites exhibited a similar pattern.

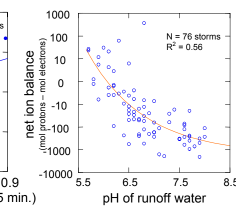

Figure 6. Ion balance of storm water runoff as a function of pH of runoff. Ion balance is the molar equivalent of the total load of all cations (Ca, Mg, Na, K, NH_4) minus the molar equivalent of the total load of all anions (HCO_3, CO_3, PO_4, NO_3, SO_4, Cl).

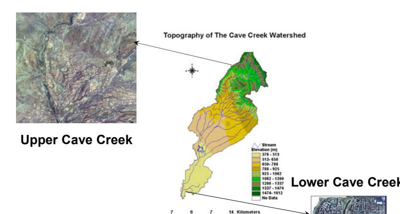

Figure 7. Study region for ongoing research of the Cave Creek Watershed. We are particularly interested in whether nutrient loading, stoichiometry, and mechanisms of retention and transport change along the urban to rural gradient. Contributory catchments to Cave Creek are our study units. Note the change in patch type and structure between upper and lower Cave Creek.