Hierarchical regulation of ecosystem function: material export from urban catchments

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WE DEMONSTRATE:

- Export of disparate materials from catchment ecosystems is influenced by attributes of storms (e.g., intensity, duration, season, etc.)
- This relationship between material load and storm attributes is shaped by intrinsic features of catchments
- Previously assumed measures of catchment features – such as the proportion of impervious ground cover – are overly simplistic and insufficient for understanding how storm attributes and catchment features interact to produce load

WE HAVE DEMONSTRATED that features of catchments influence the link between storm attributes & load.

- What are these features?
- Are they the simple descriptors typically embraced?
  - E.g., proportion of land with a certain cover type
- We argue such simple measures are insufficient to explain
  - Variability in load (Figure 8)
  - Variability in our capacity to link load to storm attributes

RESULTS

Do storm attributes influence load? **YES**

Does the relationship between load and storm attributes differ among catchments? **YES**

Does the relationship between load and storm attributes differ among materials? **NO**

How do we estimate load?

Load: total mass of a material (e.g., nitrate or lead) exported from a catchment in storm water runoff

Load is estimated by analyzing the chemistry of the “stream” of rainwater (e.g., Figure 1) flowing out of a catchment. To study this stream of runoff, a monitoring station is established at the lowest elevation point of each catchment (see Figure 3). Monitoring stations also record attributes of the storms.

Figure 1. Storm runoff flowing down a cemented river channel. This runoff was created when rainwater landed in a common urban drainage basin referred to as a “catchment,” and then gathered together along its downhill journey.

Taking a hierarchical view (see Figure 2),

WE INVESTIGATE:

1. Whether material load in storm runoff is influenced by storm attributes.
2. Whether relationships between load and storm attributes vary from one catchment to another.
3. Why the relationships between load and storm attributes differ from one catchment to another.

Figure 2. Control of ecosystem function & material load-driven through the lens of Hierachy Theory. By this theory, intrinsic, fine-scale features of a system can mediate the influence of exogenous, broad-scale forces imposed on that system.

Figure 3. This urban catchment is 1.4 hectares large with impervious cover, & is located at 45° and Pirao Avenue in Phoenix, Arizona. A monitoring station is located at the catchment’s lowest elevation point, where the “stream” of storm water runoff flows out of the catchment.

Figure 4. Study area around Phoenix, AZ.

Figure 5. Storm attributes influence the load of nitrate exported from catchments in storm runoff. Different storm attributes, however, are related to nitrate load in different catchments.

Figure 6. Our models indicate that the loads of many material species are influenced by the same storm attributes for any one catchment. This pattern holds for materials as disparate as nitrate and lead, and for the organic fraction of nitrogen, phosphorus, arsenic, and copper.

Figure 7. Each panel shows how we can use a statistical model to describe the relationship between storm attributes and the load of a particular material from a particular catchment (e.g., load of lead from Catchment 1). When we are grouping according to the catchment being considered (left panel), we can observe whether the models are similar or different. When we are grouping according to the material being considered (right panel), one is less able to guess the amount of error. In other words, the slope of points in the right-hand graphs generally more spread out than the slope of points in the left panel (values above the graph are 95% confidence intervals). CIs to the right are greater than CIs to the left. [ANNA] 0.0001 (95.3).

Figure 8. (Left) Mean (across all storm events) load of three different material species exported from a catchment plotted against proportion of impervious cover in the catchment. (Right) Y-axis value is the mean square error in regression models that fit lead as a function of storm attributes, each point is one such model fit to the load of a single material exported from a single catchment. X-axis value is the proportion of impervious cover in the catchments from which load was measured. Red line depicts a 2nd order polynomial (both terms p < 0.001).

Figure 9. Conceptualizing this hypothesis.

Figure 10. Contrasting simplification of catchments present very different amounts of information useful in elucidating knowledge-generating research design.

STOP

Figure 11. A diagram showing the relationship between storm attributes and the load of a particular material from a particular catchment (e.g., load of lead from Catchment 1). When we are grouping according to the catchment being considered (left panel), we can observe whether the models are similar or different. When we are grouping according to the material being considered (right panel), one is less able to guess the amount of error. In other words, the slope of points in the right-hand graphs generally more spread out than the slope of points in the left panel (values above the graph are 95% confidence intervals). CIs to the right are greater than CIs to the left. [ANNA] 0.0001 (95.3).

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