forWater Research Snapshot

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SUBJECT: **Forest fire effects on stream water quality at continental scales: A meta-analysis**

Research Summary

Forested watersheds supply over two thirds of the world's drinking water. The last decade has seen an increase in the frequency and intensity of wildfires that is threatening these source watersheds, and necessitating more expensive water treatment to address degrading water quality. Given increasing wildfire frequency in a changing climate, it is important to understand the magnitude of water quality impacts following fire. This study conducted a meta-analysis to explore post-fire changes in the concentrations of:

- nitrogen (N) species
- phosphorus (P) species
- dissolved organic carbon
- total suspended sediments

in 121 sites around the world (of which 81 were burned), documented in 34 research studies. Changes were documented over each study's duration, which for 90% of sites was (5) five years or fewer.

This study used a meta-analysis approach to explore the interactions between element cycles in post-fire landscapes, and the effect of fire on the concentration distribution. The specific objectives were to:

(a) quantify the effect of fire on the changes in concentrations of suspended sediments, nitrogen, phosphorus and carbon species,

(b) quantify the degree of covariation between the concentrations of these elements in post-fire landscapes, and

(c) quantify the effect of fire on concentration distributions.

The most commonly sampled parameter was nitrate (NO_3^-)(at 67 of 81 sites), followed by total phosphorus (TP)(41), total nitrogen (TN)(31), ammonium (NH_4^+)(30), total suspended solids (TSS)(26), phosphate (PO_4^{3-})(20), dissolved organic carbon (DOC)(17), and dissolved organic nitrogen (DON)(14). Only 47% of sites had more than one year of data post-fire, with the greatest data density for NO_3^-. Further, only 9% of sites were sampled beyond five years after the fire. Wildfire studies tend to focus on collecting samples over a short timeframe, making it challenging to evaluate recovery times.

Research Results

- Overall, concentrations of nutrients and sediments increased after fire, with the largest increases observed for NO_3^-, TP, and NH_4^+, with smaller increases for PO_4^{3-}, TN, DOC, and TSS. When exploring the coupling of nutrient cycles, increases in one element generally predicted an increase in another element.
- Fire alters N and P speciation, with median increases of 40–60% in the proportion of soluble inorganic N and P relative to total N and P.
- Fire decreases C:N and C:P ratios, with median decreases ranging from 60% to 70%.
- Increases in dissolved inorganic nutrients in the immediate aftermath of the fire can be attributed to a variety of reasons, including: (a) subsurface release due to suppressed nutrient uptake by terrestrial biota, (b) ash deposits from the fire as a source of dissolved organic and inorganic

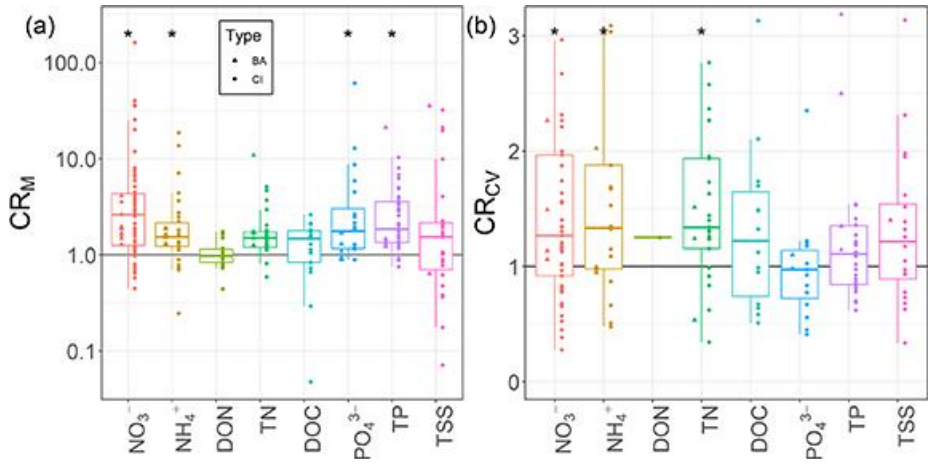
nutrients, and (c) inhibition of in-stream processes, such as NO_3^- uptake, due to lower DOC export and a more aromatic DOC signature from burned watersheds.

- Concentration increases were greater during rare but extreme elevated concentrations. The increase in concentration extremes in the post-fire period has significant implications with respect to water treatability for downgradient communities that might be using the river as a water source.
- The study documented strong heterogeneity in responses of water quality to wildfire that have been unreported so far in the literature.

Key Messages

- Wildfire frequently increased the concentrations of nitrogen and phosphorus species in streams.
- The meta-analysis demonstrated the large variability in post-fire water quality responses.
- Shifts in nutrient ratios increased bioavailable fractions of nitrogen and phosphorus. The changes in these ratios are important to the downstream ecosystem and potential for algal growth. These bioavailable compounds might pose greater eutrophication risk downstream. Much is yet to be learned about these altered ratios in post-fire landscapes.
- It is recommended that future studies focus on capturing high concentration events that often co-occur with high flow events. The meta-analysis highlights the need for continued long term monitoring of water quality in post-fire landscapes, along with the exploration of covariation between multiple elemental cycles and storm driven responses in concentration extremes.

Figure 1



Change ratios (CR) for (a) mean concentration change (CR_M) and (b) change in coefficient of variation - CV (CR_{CV}). A change ratio of 1 indicates no change. Each point is one burned catchment site, with study type represented as shapes (before-after as triangle, control-impact as circle). Boxplots are shown for all before-after and control-impact sites combined. Stars above each parameter indicate that the population of change ratios has a mean significantly ($p < 0.05$) different from 1 (*t*-test performed on the log of change ratios).

Reference: Hampton TB, Lin S, Basu NB. 2022. Forest fire effects on stream water quality at continental scales: A meta-analysis. *Environmental Research Letters*, 17(6):064003, DOI 10.1088/1748-9326/ac6a6c.

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