Does drought affect nitrate and phosphate concentrations in the same way throughout a stream network?

Extreme drought conditions increase variability of nitrate through a stream network, with limited influence on the spatial patterns of stream phosphate

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Are nitrate and phosphate availability affected by drought conditions in western North American stream networks? The authors investigated spatial and temporal differences in nitrate and phosphate in three sections of the McRae stream network in the HJ Andrews experimental forest, Oregon. They sampled nutrient concentrations at 233 locations over 11.5 km during three time periods during varying levels of drought in 2015 and 2016. The researchers examined whether changing flow regimes and increased drought expected with changing climate conditions would alter nutrient transport and availability throughout the basin.

Did stream flow differ among sampling periods?

Flow during the sampling periods was between 31% and 48% of historical mean flows and ranked in the lowest five discharge levels for each of the weeks. During sampling, flow was highest during June 2016 and lowest during August 2015.

Did nutrient concentrations differ spatially and temporally?

At the stream segment level, nitrate concentrations varied across the sampling periods and were highest during the August 2015 sample in both McRae Creek mainstem and McRae Creek tributary east. Nitrate concentrations were similar through time in McRae Creek tributary west.

Nitrate concentrations varied within stream sections during each sampling period. Variation in nitrate was highest during the August 2015 sampling and lowest during the June 2016 sampling in all three stream segments.

Phosphate concentrations were highest during June 2016 in the McRae Creek mainstem and McRae Creek tributary west and lowest during June 2016 in McRae Creek tributary east.

Did relative nutrient concentrations differ across the stream network?

The nitrate to phosphate ratio was higher in the higher stream reaches, especially the upper 2 km of McRae Creek mainstem, which corresponded with the pattern of decreasing nitrate and increasing phosphate with distance downstream.

Variability of the ratio of nitrate to chloride was greater in August 2015 than in June 2016, which is consistent with nitrate concentration patterns. The ratio of phosphate to chloride generally increased with distance downstream, which is the generally the same pattern as phosphate concentration.

Based on the nitrate to phosphate ratio, phosphate may be the limiting nutrient in one section of the upper mainstem of McRae Creek, but in all other sections nitrate is likely limiting.

How did nutrient concentrations respond to drought conditions?

Analysis of semi-variance indicated that nitrate concentrations were more spatially variable and the autocorrelation distance was higher during low drought conditions, likely because transport and surface water inputs were lower, which increased the importance of local nitrate input and retention.

Phosphate concentrations were more spatially variable during high flow conditions. Similar to nitrate, chloride concentrations were greater during more intense drought conditions.

Phosphate availability was similar during the period of drought and the period that the water level was decreasing. Phosphate concentrations increased with downstream distance, suggesting the inputs were greater than in-stream processing. The spatial and temporal pattern of the phosphate to chloride ratio was generally the same as the pattern of raw phosphate.

What should I keep in mind when reading or designing studies on nutrient availability in streams?

Nitrate concentrations are caused by different processes in different stream segments. The nitrate to chloride ratio decreased with distance downstream in the uppermost section of McRae Creek, similar to decreases in nitrate concentration, indicating that decreasing nitrate concentrations resulted from local-scale nitrate processing. However, in lower reaches of the mainstem, spatial variability of nitrate and chloride concentrations indicated differing groundwater source inputs.

Nutrient concentrations were more spatially variable during low flow conditions. Therefore, studies during low flow conditions will require a larger number of sampling locations to achieve the desired level of accuracy and these locations will need to be closer together.

Research Approach/Methods

- Water samples were collected every 50 m of McRae Creek and its two main tributaries during three periods in 2015 and 2016, two during the dry-down phase and one during baseflow.
- All samples were filtered, frozen, and later sampled for nitrate, phosphate, and chloride.
- Researchers determined spatial patterns of each nutrient during each sampling period and assessed how changes in summer discharge impacted patterns of nutrient concentrations.
- They also assessed whether both local input and local uptake of nutrients had greater impact on nutrient concentrations in surface water during low flow conditions and whether nutrient concentrations were more spatially variable during extreme drought conditions.

Keywords Nitrogen, Phosphorous, stream network, semi-variance analysis, drought, stream spatial patterns, H.J. Andrews

Images

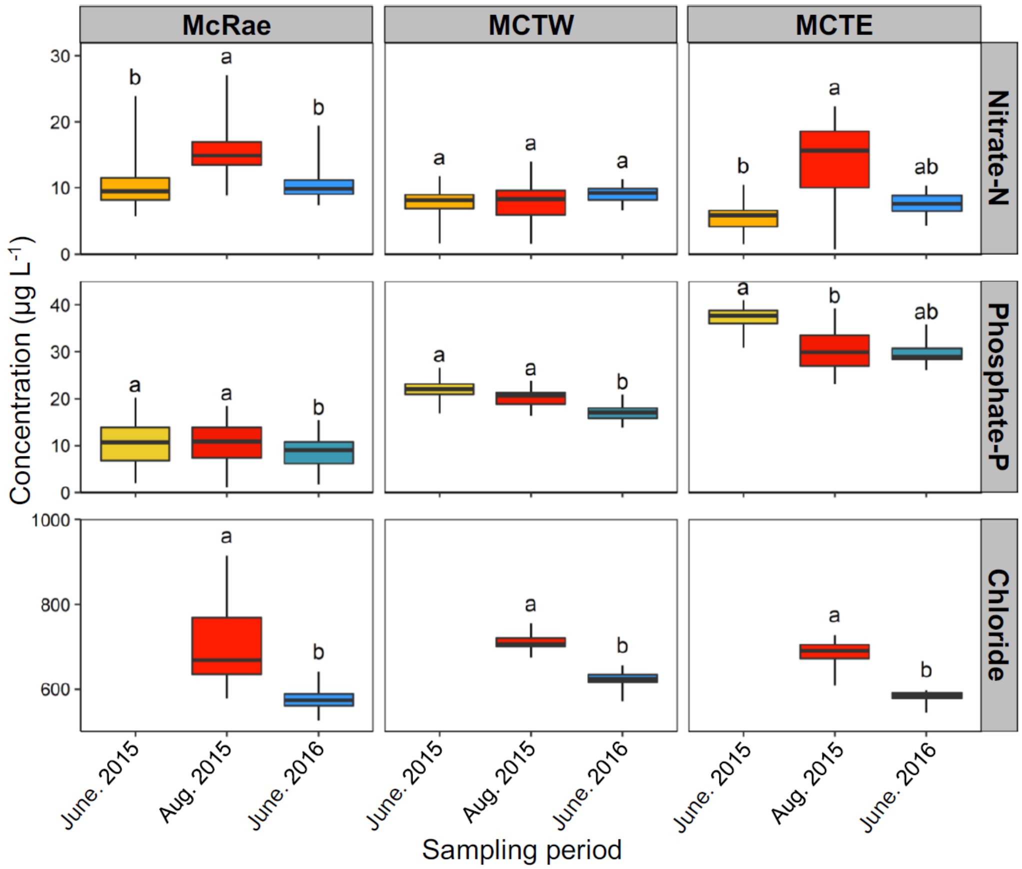

Fig. 3 in Warren at al. 2022. Boxplots of nitrate‑N (upper panels), phosphate-P (middle panels),and chloride (lower panels) concentrations during the three sampling periods in McRae Creek mainstem, and tributaries MCTW, and MCTE. Plot whiskers indicate 10th and 90th percentiles. Letters indicate significance groupings from Tukeys HSD.

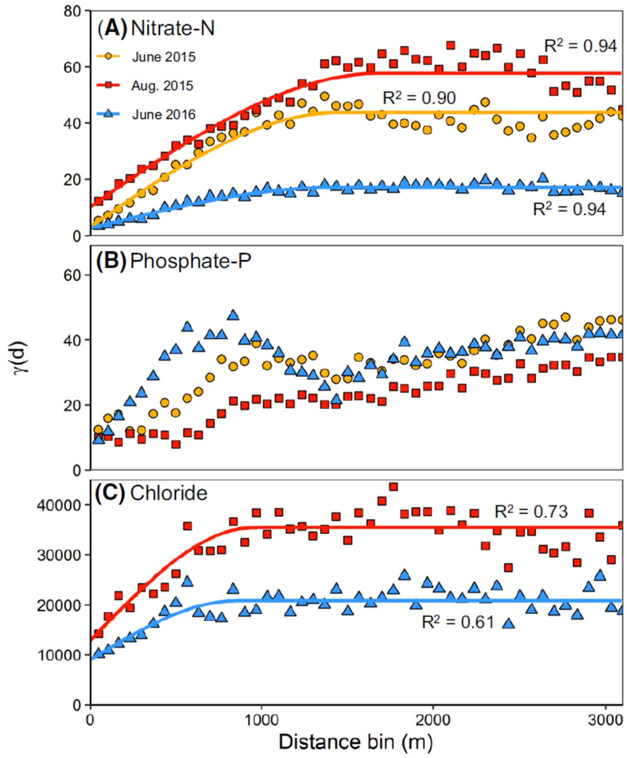

Fig. 8 Warren et al. 2022. Semi-variance of nitrate-N (**A**), phosphate-P (**B**), and chloride (**C**) through the McRae Creek network during moderate (June 2016) and severe (June and August 2015) drought conditions. Fitted lines are spherical models with the quality of the fit expresses as an r^2 value. The x-axis indicates lag distances between points for the semi-variance analysis.

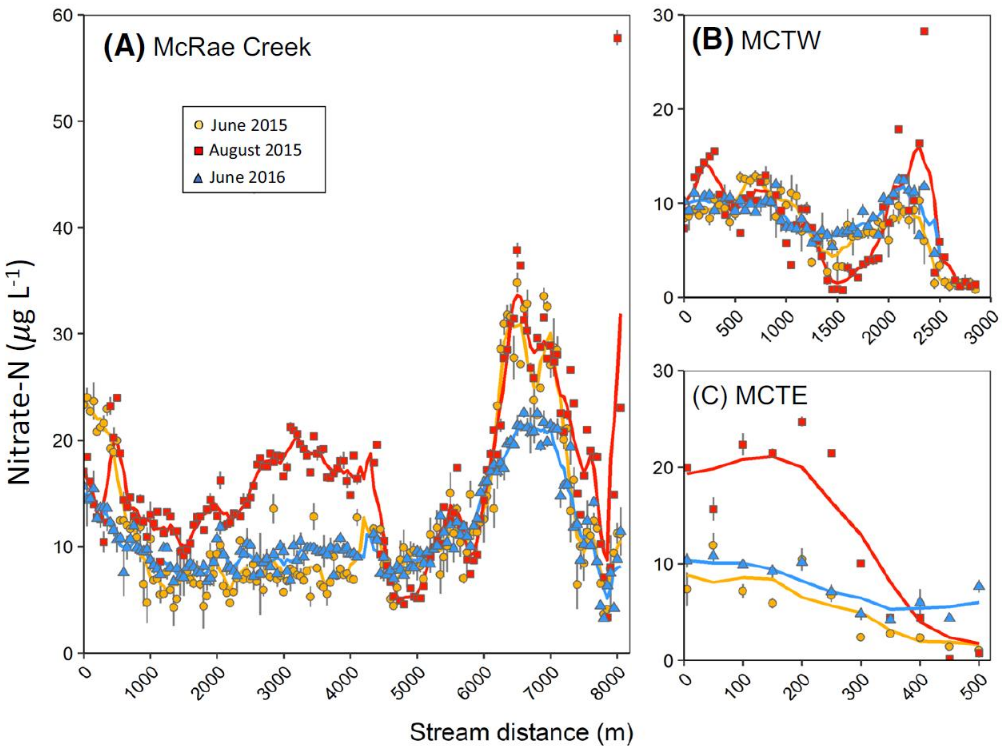

Fig. 4 in Warren et al. 2022. Spatial pattern of NO_3^-–N in June 2015, August 2015, and June 2016, throughout the mainstem, McRae Creek (**A**) and its two major tributaries, MCTW (**B**) and MCTE (**C**). The x-axis values represent **A** distance from confluence between McRae Creek and Lookout Creek, **B** distance from the confluence between MCTW and McRae Creek mainstem, and **C** distance from the confluence between MCTE and McRae Creek mainstem. Error bars are ± one standard error from the three replicate samples collected at each location.

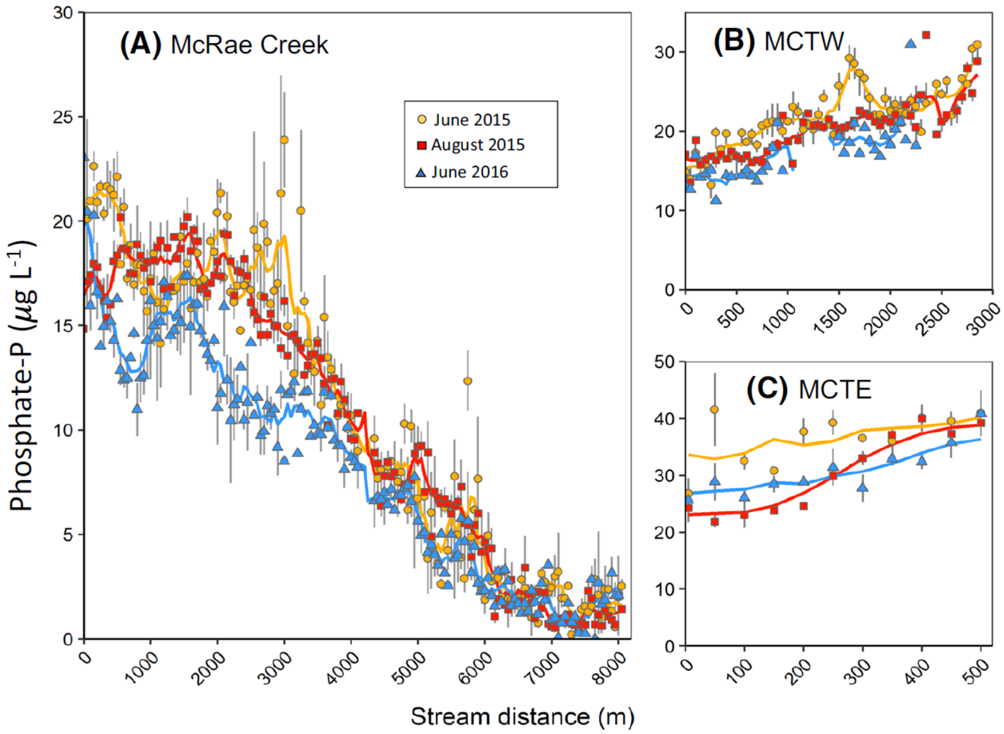

Fig. 5 in Warren et al. 2022. Spatial pattern of PO_4^{-3}-P in June 2015, August 2015, and June 2016, throughout the mainstem, McRae Creek (**A**) and its two major tributaries, MCTW (**B**) and MCTE (**C**). The x-axis values represent **A** distance from confluence between McRae Creek and Lookout Creek, **B** distance from the confluence between MCTW and McRae Creek mainstem, and **C** distance from the confluence between MCTE and McRae Creek mainstem. Error bars are ± one standard error from the three replicate samples collected at each location.