1. Project

Title: Ecological and biogeochemical hotspots along boreal streams: Recommendations for best-management-practice of riparian buffers

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2. Popular science summary:

Riparian hotspots along boreal streams and rivers are closely linked to discharge of upland-originated groundwater (GW). In our previous research we showed that riparian GW discharge hotspots have high biodiversity and distinct soil chemistry, and may thus embody substantial control over stream water quality. Thus we suggested that the protection of these areas from perturbation caused by forest management is essential, but also that more research was needed in order to understand the biogeo-chemical influences of GW discharge. Due to the financial support from Skogsällskapet we were able to extend and complement our understanding of the GW discharge hotspots. We established a permanent infrastructure of GW wells and completed three sampling campaigns. We monitored GW wells at 11 pairs of GW discharge and non-discharge sites situated along three headwater streams in the Krycklan catchment in Västerbotten. The result of the sampling campaigns showed that GW chemistry is substantially different between the pairs of discharge and non-discharge sites in respect to for example electrical conductivity, total carbon concentrations and base cations. Overall our results demonstrate that GW discharge locations in boreal riparian zones embody large control over stream water quality and quantity. Therefore, we strongly suggest that management of riparian buffers, associated with forestry operations, abandon the long time utilized fixed-width concept. Instead, riparian buffers should be hydrologically adapted, wider on areas with GW discharges and narrower on drier places. We presented these ideas at the recent Krycklan symposium (September 2016) and were met with a lot of enthusiasm from researchers and forest authorities. Therefore, we will continue research on this work as well as implement our findings and recommendation to the best-management practice of Swedish forestry.

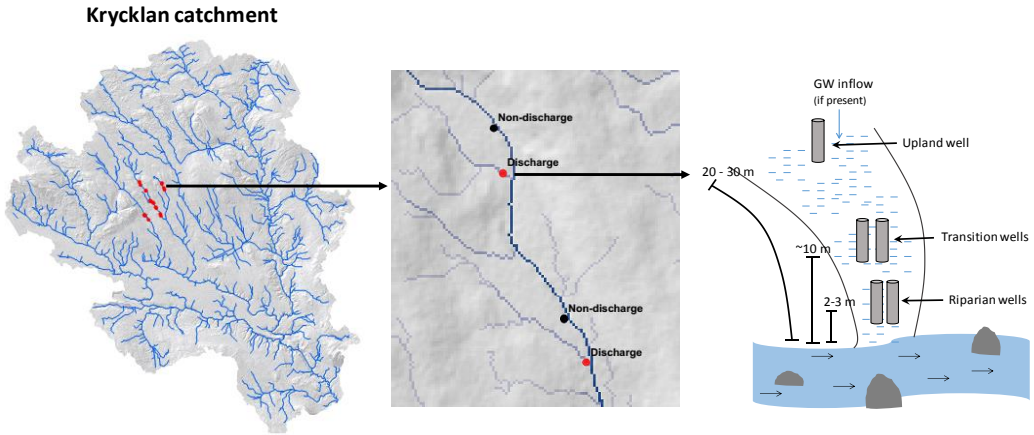

Figure 1. Placement of 22 riparian sites (11 with GW discharge and 11 without) along three headwaters in the Krycklan catchment (red points in the left panel). A detail of 2 pairs of sites with and without GW discharge is displayed in the center on simplified GW flow accumulation model (darker color represent more water). The schematic design of GW wells installation at each site is illustrated to the right.

3. Results

3.1 Permanent GW well monitoring stations installation

We have installed GW wells at 11 pairs of GW discharge and non-discharge sites along 3 headwater streams within the Krycklan catchment (Fig. 1). For the site selection, a hydrological model of GW flow paths was created (A. Ågren, simplified version of the model on Fig. 1) and the GW discharge locations were visually confirmed in the field. At each site we installed 5 GW wells in total (Fig. 1), at three distances from the stream, i.e., 3 m (two riparian wells), 10 m (two transition wells) and 20-30 m (one upland well). The wells were installed in depth between 50 and 200 cm, based on local soil structure and depth to bedrock. For the paired wells (i.e., riparian and transition), one well is used for GW sampling and one well for water level and temperature monitoring. Due to instrument failures we were not able to continuously monitor GW levels and temperature, however new instruments will be installed shortly (TrueTrack water level loggers, New Zealand). The GW wells installation was finalized in August 2015 (example on Fig. 2). The wells are installed permanently and will continue to be monitored in the coming years.

Figure 2. An example of GW discharge (left) and non-discharge (right) sites with riparian and transition wells. Pictures are taken standing in the stream. Photos by L. Kuglerová

3.2 GW sampling campaigns and analyses

Three GW sampling campaigns were completed during different hydrological conditions. The fist sampling occurred during dry period with no significant precipitation prior to sampling (August 2015), the second after spring flood (May 2016) and the third during high precipitation event (July 2016). Samples were taken according the standard GW sampling protocol using suction lysimeters. Manual measurements of GW depth were collected during sampling.

Manual measurements confirmed the differences in GW table depth between the paired sites. At GW discharge sites, GW table was often close to soil surface (0-20 cm deep) while at non-discharge sites the table was substantially deeper (> 50 cm). Similarly, GW chemistry was highly dependent on GW discharge conditions, as well as on the distance from the stream. Many of the chemical compounds measured has similar trends over the three sampling campaigns, and the differences in GW chemistry was often highest in the riparian wells (i.e., closest to the stream). For example, electrical conductivity was lower at GW discharge sites for both riparian and transition wells but did not differ at the upland wells. This trend was well correlated with concentration of base cations which were also lower at the GW discharge sites (Appendix 1). Water pH was also lower at the discharge sites but the differences were visible only at the riparian wells. The pH trends were well explained by the concentrations of

TOC, which was higher at the GW discharge riparian wells (Appendix 1). Many other chemical compounds followed similar trends (e.g., anions, nitrate, ammonia). We also found that the presence of discharging GW was possible to trace by measuring thermal regimes and chemistry within the adjacent streams (Appendix 1). **We are currently running statistical analyses on the data and planning additional sampling campaigns to strengthen our results and reveal general trends.** Nevertheless, these first results strongly suggest the biogeochemical uniqueness of GW discharge in boreal riparian zones and the tight coupling between hydrology and water chemistry. Thus we believe that these wet areas need to be better considered during forestry operations by leaving wider buffers to protect biodiversity and by avoiding machine operations (driving) in order to avoid soil rutting and consequent biogeochemical decoupling. Finally, we confirmed that modeled GW discharge is a useful tool for such wet sites identification and can be easily used by practitioners.

4. Communication

The results of this study were presented on the Krycklan symposium and workshop in September 2016 (funded partly by Skogsällskapet, partly by Future Forest). The workshop was organized as a part of the project to bring together researchers, local authorities and practitioners to discuss the optimal management of riparian buffers along small boreal streams. We invited speakers from different countries (Canada, Finland, UK) to share experiences and exchange ideas. The workshop was very successful and the outcome of the discussions will be presented in an opinion article. The first popular science summary of the Krycklan symposium and workshop can be found at: http://www.slu.se/ew-nyheter/2016/10/fina-backar-och-fula-diken-forskarmote-om-dikesskotel-och-vattenskydd/. Part of the results was also presented at the conference of European Geoscience Union in April 2016.

Further the project outcomes will be presented in following publications:

- Leach, J.A., Lidberg, W., Kuglerová, L., Ågren, A., Laudon, H. Evaluating terrain-based predictions of shallow lateral groundwater discharge zone along a boreal stream. *WWR* (in review)
- Kuglerová, L. Hasselquist, E., Laudon, H. et al. A management perspective on Aqua Incognita & beyond. *HP* (in prep.)
- Kuglerová, L., Peralta-Tapia, A., Ploum, S., Ågren, A., Laudon, H. Understanding the biochemical regimes of groundwater discharge riparian hotspots. (in prep.).

The framework of this project was further used for other grant applications and we were pleased to be granted 3 mil. SEK from the Swedish Research Council Formas and 2 mil. SEK from the Oscar and Lili Lamms foundation (to H. Laudon as the main applicant and L. Kuglerová as co-applicant). A PhD student (Stefan Ploum - SLU) was appointed to carry on with the work. The GW wells are also used in multiple other projects at SLU, for example investigating carbon fluxes, nitrogen dynamics and hydrological connectivity. Overall this project has brought together researchers from various field and attracted the attention of public sector as well as funding organizations.