

Report by UWI doctoral researcher Mikael Gillefalk (N5)

Project number: N5

First and last name of doctoral researcher: **Mikael Gillefalk**

(Working) title of doctoral project: **Effects of Bank filtration on lake water ecosystems**

Name of supervisors: PD Dr. Sabine Hilt (IGB), Prof. Dr. Wolf Mooij (NIOO¹), Prof. Dr. Mark Gessner (IGB & TUB), Prof. Dr. Reinhard Hinkelmann (TUB), Dr. Michael Hupfer (IGB)

2. Description of doctoral project and research results achieved to date:

Motivation

Bank filtration describes the process of surface water infiltrating into the groundwater from lakes or rivers. In large parts of the world, especially in Central Europe, this phenomena is induced by installing groundwater wells close to surface water bodies, lowering the groundwater surface (Ray et al., 2003). The passage through the soil functions as a first, cost-efficient cleaning step for drinking water production. Earlier research dealing with induced bank filtration has focused on the abstraction capacity and the cleaning efficiency. With the research project N5, we want to change perspective and instead focus on ecosystems.

Aim

The overall aim of project N5 is to investigate the effects of induced bank filtration on lake ecosystems, thereby opening a new research field. Our goal is to carry out fundamental research, studying particular parameters, bringing the state of the art forward but also not to forget the broader picture and be able to provide a knowledge base upon which well-informed decisions about lake management can be made. These two aims go hand in hand.

Methods

The research has been divided into three parts.

- 1) First, since the research field in many aspects is new, a fundament was required to be laid. We needed to come up with what effects induced bank filtration could have and then search in the literature to see what those effects could have on a lake or river ecosystem. This was done with reasoning and by an extensive literature review.
- 2) Second, the ecosystem model PCLake was used to simulate the effects of induced bank filtration on shallow lakes.
- 3) Third, sediment samples were collected from Lake Müggelsee, Berlin, a lake where induced bank filtration has been ongoing for more than 100 years to test whether different pumping rates have an effect on sediment characteristics such as organic content and phosphorus concentrations and whether such changes affect macrophyte and periphyton growth.

Current State of Work

The literature review has shown that a number of effects are possible and we have divided them into three categories: physical, chemical and biological (Fig. 1). The physical and the chemical parameters and processes affect each other as well as the biological ones, all of them have an effect on the surface water quality. An informative example is the CO₂ availability for macrophytes (water plants) in lakes. In the typical case, a lake in a pristine condition receives groundwater, exfiltrating through the sediments in the littoral zone. This water usually has a higher concentration of CO₂ than does the lake water (Weyenmeyer et al., 2015, Marcé et al., 2015). Therefore, groundwater exfiltration increases the growth of macrophytes, since higher CO₂ concentrations promotes macrophyte growth (Madsen and Sand-Jensen, 1994). When installing groundwater wells to induce bank filtration, this groundwater exfiltration is interrupted, which lowers the CO₂ availability and leads to worsened growth conditions for the macrophytes and risks shifting a lake from a clear-water state to a turbid state (Scheffer et al., 1993). The work resulted in a manuscript that has been submitted to Water.

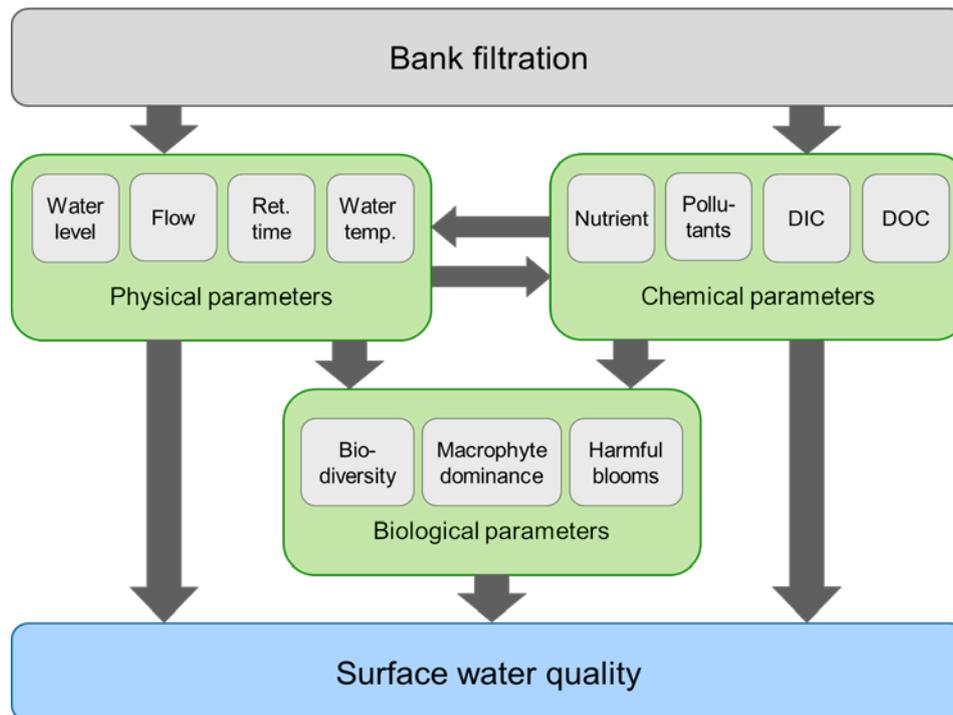


Figure 1: Conceptual scheme of potential links between induced bank filtration and relevant parameters and processes concerning surface water quality (from Gillefalk et al., under review in Water). DIC = dissolved inorganic carbon, DOC = dissolved organic carbon.

The modelling work used the findings of the literature review to choose parameter values and combinations. We used the ecosystem model PCLake (Janse, 2005) and most of our simulated scenarios increased the phytoplankton abundance and thus had adverse effects on shallow lake water quality (Fig. 2). Threshold levels for critical nutrient loading inducing regime shifts from clear to turbid conditions were up to 80 % lower with induced bank filtration indicating a decreased resilience to eutrophication. Critical nutrient loads determine how resilient a lake is to increasing or decreasing nutrient loads. How the critical loads are shifted depends on the lake's initial conditions, especially in regard to groundwater flow and quality (nutrient and CO₂ concentration), but also lake size and depth play a role. We found that effect of induced bank filtration were stronger when a lake was smaller and shallower.

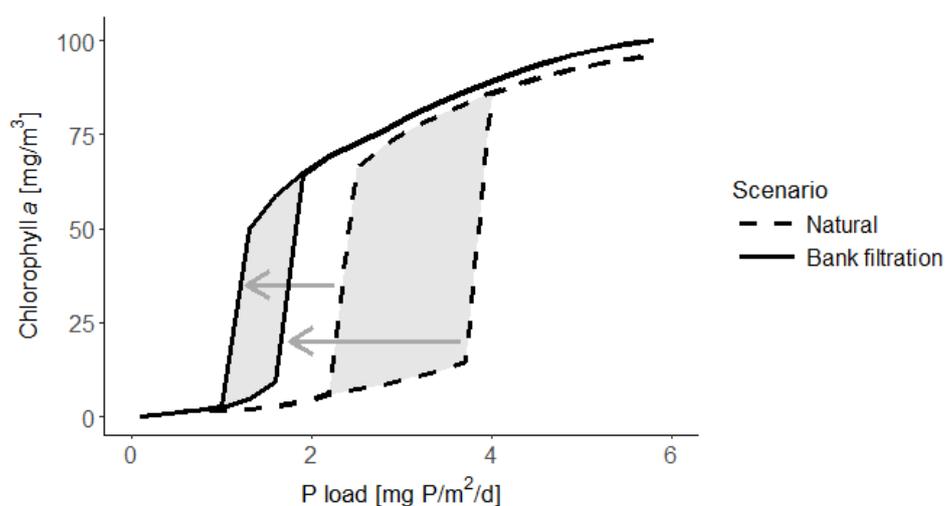


Figure 2: Chlorophyll *a* concentrations depending on phosphorus (P) loading in a standard shallow lake with exfiltration of groundwater (natural) or induced bank filtration using average parameter values: Shaded areas indicate zones of hysteresis, arrows indicate the impact of induced bank filtration on critical nutrient loads (changed after Gillefalk et al., under review in Water Research).

The modelling work has been performed in close collaboration with a working group led by Prof. Wolf M. Mooij at the Netherlands Institute of Ecology (NIOO, Wageningen) and has resulted in a manuscript submitted to Water Research that is currently under review.

The third part of the project is still ongoing. The aims are to investigate whether different pumping rates of the groundwater wells surrounding Lake Müggelsee have an effect on sediment characteristics such as organic content and phosphorus concentrations and whether such changes affect macrophyte and periphyton growth. The field and lab work has been finished and consisted of collecting sediment samples and tubers from the macrophyte *Potamogeton pectinatus*. The sediment samples were analysed with regard to dry weight, loss on ignition and plant available phosphorus. The sediment samples were also used for growth experiments using the above named tubers. During the experiments, the growth of periphyton (Fig. 3) was also measured. What still remains is the final analysis of the results and the writing of a third manuscript. The field and laboratory work was conducted with the help of Anna Stelmecke, a master student doing an internship at IGB and by Simon Pötter, who spent three months of his “Voluntary ecological year” at IGB. This gave me very good training in supervising students and interns.



Figure 3: Periphyton sampled from a laboratory experiment on the effect of sediment sampled from sites with different bank filtration activities in lake Müggelsee.

Collaboration

The doctoral project N5 is part of the common topic groups “Interfaces in urban surface water”, “Modelling” and “Surface water – groundwater interactions”. The last group’s work resulted in a conference paper (Tabea Broecker et al., 2017).

Regarding limnological research questions and approaches, there was a close exchange with research project T4.

The modelling work was possible thanks to a close collaboration with the Netherlands Institute of Ecology resulting in a manuscript submitted to Water Research (first author: Mikael Gillefalk).

A good relationship with the Berlin Water Utilities and the Berlin Senate Department for the Environment, Transport and Climate Protection has made it possible to obtain valuable data regarding pumping rates and flow conditions for Lake Müggelsee. Together with PD Dr. Sabine Hilt I had a meeting with the latter institution, where we discussed this project.

Supervision

Supervision of master student Anna Stelmecke from TU Dresden during March-April 2016 during her internship at IGB. Her work consisted of field work (sediment sampling), laboratory work, statistical analysis and report writing.

References

1. Janse, J.H. (2005): Model studies on the eutrophication of shallow lakes and ditches. PhD thesis, Wageningen University, The Netherlands. ISBN 90-8504-214-3
2. Madsen, T.V. & Sand-Jensen, K. (1994): The interactive effects of light and inorganic carbon on aquatic plant growth. *Plant Cell Environ.* 17, 955–962
3. Marce, R., Obrador, B., Morgui, J.-A., Lluís Riera, J., Lopez, P. & Armengol, J. (2015): Carbonate weathering as a driver of CO₂ supersaturation in lakes. *Nat. Geosci.* 8, 107–111
4. Ray, C., Schubert, J., Linsky, R.B. & Melin, G. (2002): Introduction, in: Ray, C., Melin, G., Linsky, R., B. (Eds.), *Riverbank Filtration: Improving Source-Water Quality*, Water Science and Technology Library. Kluwer Acad. Publ, Dordrecht, pp. 1–15
5. Scheffer, M., 2004. *Ecology of Shallow Lakes*. Springer Netherlands, Dordrecht

6. Weyhenmeyer, G.A., Kosten, S., Wallin, M.B., Tranvik, L.J., Jeppesen, E. & Roland, F. (2015). Significant fraction of CO₂ emissions from boreal lakes derived from hydrologic inorganic carbon inputs. *Nat. Geosci.* 8, 933-936

3. Comments on the qualification programme and supervision strategy:

The core courses helped me to get a broader understanding of both engineering and natural science when it comes to question of urban water interfaces. The statistical courses I attended have been of great help when analysing my own work but also understanding what other scientists are doing. Having Summer school's to go to helped me pause, zoom out and take a look at where I was in my work, since I know I had to give a presentation to a fairly broad audience. That helped my structure and plan my work better than I otherwise would have been able to. It was also a great way of meeting my fellow PhD candidates, as well as the kollegiates and the senior scientists, and benefit from their expertise.

I like the fact that I have a board of supervisors, even though it is hard to get to see all of them at once. It gives the opportunity to get feedback on the planning and general strategy from scientists that work in different fields and therefore might have different views on how to proceed in different circumstances.

Participation in the following Research Training Group events:

1. Core courses

- I – Urban interface processes – fluxes, transport, interactions (3 ECTS)
- II – Modelling and measuring concepts of interface processes (3 ECTS)
- III – Urban freshwater ecology (3 ECTS)

2. Elective courses

- Advanced statistics: Selected multivariate methods in R (IGB) (3 ECTS)
- Advanced statistics: general(ized) linear mixed models (IGB) (4 ECTS)

3. UWI lectures and Colloquia at IGB and TU: Participated in all UWI lectures as well as around 50 other lectures given at IGB and TU (3 ECTS)

4. Other UWI events

- Orientation Seminar and UWI Opening Ceremony (08.-09.09.2015)
- Exposé Talks (08.12.2015)
- Kollegiate/Fellows Seminar (22.09.2016)
- Interim Meeting (19.05.2017)
- Summer School (13.-14.09.2016 and 05.-06.09.2017)
- Summer School (18.-20.09.2018)

Research stays or internships at other research institutions both at home and abroad.

Netherlands Institute of Ecology (NIOO, Wageningen), 13.11.-08.12.2016 and 15.10.-08.11.2017

Participation in conferences, congresses, etc., at home and abroad:

2016:

- 6th German-Russian Week of the Young Researcher (12.-16.09.2016, Moscow, Russia).
- Limnologie der Zukunft / Zukunft der Limnologie (26.-30.09.2016, Vienna, Austria)

2017:

- Wasser Berlin International, Berlin (28.-31.03.2017)
- Symposium for European Freshwater Sciences (02.-07.07.2017, Olomouc, Czech Republic)

2018:

- EGU General assembly (08.-13.04.2018, Vienna, Russia)

4. Individual publications:

I. Articles:

- Aichner, B., Hilt, S., Perillon, C., Gillefalk, M. & Sachse, D. (2017): Biosynthetic hydrogen isotopic fractionation factors during lipid synthesis in submerged aquatic macrophytes: Effect of groundwater discharge and salinity. *Organic Geochemistry* 113, 10–16
- Gillefalk, M., Massmann, G., Nützmann, G. & Hilt, S. (2018): Potential Impacts of Induced Bank Filtration on Surface Water Quality: A Conceptual Framework for Future Research. *Water*, 10(9): 1240
- Hilt, S., Alirangues Nuñez, M.M., Bakker, E.S., Blindow, I., Davidson, T.A., Gillefalk, M., Hansson, L.-A., Janse, J.H., Janssen, A.B.G., Jeppesen, E., Kabus, T., Kelly, A., Koehler, J., Lauridsen, T.L., Mooij, W.M., Noordhuis, R., Phillips, G., Ruecker, J., Schuster, H.-H., Sondergaard, M., Teurlinckx, S., van de Weyer, K., van Donk, E., Waterstraat, A., Willby, N. & Sayer, C.D. (2018): Response of Submerged Macrophyte Communities to External and Internal Restoration Measures in North Temperate Shallow Lakes. *Front. Plant Sci.* 9, 194

II. Conference, poster presentations etc.:

- Broecker, T., Schaper, J., El-Athman, F., Gillefalk, M., Hilt, S. & Hinkelmann, R. (2017): Surface water - groundwater interactions, in: *37th IAHR World Congress*, Kuala Lumpur, Malaysia. Reviewed paper.
- Gillefalk, M., Broecker, T., El-Athman, F., Nega, M., Schaper, J., Hinkelmann, R. & Hilt, S. (2016): Urban Water Interfaces: Surface Water - Groundwater Interactions, *6th German-Russian Week of the Young Researcher* (12. – 16.09.2016, Moscow, Russia), abstract and oral presentation
- Gillefalk, M., Stelmecke, A. & Hilt, S. (2016): Effects of Bank Filtration on Lake Ecosystems, *DGL Tagung - Limnologie der Zukunft / Zukunft der Limnologie* (26.-30.09.2016, Vienna, Austria), abstract and oral presentation
- Gillefalk, M. & Hilt, S (2017)., Effects of Bank Filtration on Lake Ecosystems. *IGB Department II Colloquium* (18.04.2017, Berlin, Germany), oral presentation
- Gillefalk, M., Mooij, W.M., Teurlincx, S., Janssen, A.B.G., Janse, J.H., Chang, M. & Hilt, S. (2017): Evaluating the impact of bank filtration on lake ecosystems using a shallow lake model. *Symposium for European Freshwater Sciences* (02.-07.07.2017, Olomouc, Czech Republic), abstract and oral presentation
- Gillefalk, M., Nunez, M.M.A, Hilt, S. (2017): Macrophytes and their unnoticed stressors. *IGB Science Day* (07.12.2017., Berlin, Germany), oral presentation
- Gillefalk, M., Mooij, W.M., Teurlincx, S., Janssen, A.B.G., Janse, J.H., Chang, M. & Hilt, S. (2018): Bank filtration affects shallow lake ecosystems: evidence from model scenarios. *EGU General assembly* (08.-13.04.2018, Vienna, Austria), abstract and PICO (Presenting Interactive Content)