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# Effect of riparian vegetation on diatom assemblages in headwater streams under different land uses

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## HIGHLIGHTS

- Diatoms in headwaters with different riparian cover and land use were compared.
- We assessed diatom assemblage structure, structure of diatom guilds and IPS index.
- Diatoms at impacted sites were similar regardless of the status of riparian cover.
- Diatoms assemblages were mainly driven by urbanization and nutrients.
- Riparian vegetation did not buffer impacts of the catchment land use on diatoms.

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## ABSTRACT

Differences in the structure of diatom assemblages in headwaters with contrasting shading conditions and different land use in the buffer zone and upper catchment were studied in order to evaluate the influence of the lack of riparian vegetation on the biofilm. The objective was to ascertain whether a riparian buffer can mitigate the negative influence of human induced disturbance and pollution on diatom assemblages in headwaters. Four streams were selected in order to maximize the differences in the land cover and minimize other environmental gradients. Multivariate statistics, different comparative and permutation tests and correlations were applied to compare the diatom assemblages, the Specific Polluosensitivity Index (IPS) and the diatom ecological guilds (low profile, high profile and motile) among the sites studied and to evaluate their responses to disturbances. The analysis showed that low profile diatoms typically dominated in forested headwaters with limited resources, whilst assemblages at impacted sites showed a wider range of growth forms. In unimpacted streams, the diatom assemblages were influenced by temperature, pH, conductivity and calcium, as usually reported for oligotrophic streams with high natural disturbance due to fast current and shading. In both shaded and unshaded impacted streams, the importance of nutrients and land use disturbance, especially urbanization, prevailed. This trend was also reflected by the IPS index that showed consistently lower values at impacted sites, correlating most significantly with nutrients. The diatom species composition as well as diatom guilds at impacted sites were similar, regardless of the presence or absence of riparian vegetation, and were significantly influenced by seasonal changes.

Our results indicate that diatoms react sensitively to alterations of the water environment in headwaters, induced by anthropogenic activities, and these impacts are not buffered by an intact riparian zone. Diatoms closely reflected land use practices in the upper catchment regardless of the buffer zone status.



## 1. Introduction

The importance of the role of riparian vegetation in determining the structure and function of stream ecosystems has long been recognized (Vannote et al., 1980; Knight and Bottorff, 1984; Richardson and Danehy, 2007). Headwater streams are greatly influenced by riparian vegetation since they function as processors of organic matter coming from the watershed (Cummins and Spengler, 1978). The riparian interface regulates stream temperature (Hetrick et al., 1998; Moore et al., 2005; Studinski et al., 2012) and is reported to function as a filter, buffer and stabilizer (Keller and Swanson, 1979; Knight and Bottorff, 1984; Sabater et al., 2003). These effects are particularly strong in forested headwaters (Studinski et al., 2012). Headwater streams and their riparian areas differ from downstream reaches in a number of fundamental ways that shape their characteristic biological communities (Richardson and Danehy, 2007). These streams are characterised by small channel size, closed canopy resulting in reduced light conditions, higher input rates of organic matter and low primary production. The predominance of organic matter favours detritus-based communities

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(Richardson and Danehy, 2007), whilst the biomass of primary producers, such as algae, is limited due to reduced light (Sabater et al., 1998; Greenwood and Rosemond, 2005). Thus, the removal of riparian vegetation reduces inputs of detrital organic matter and increases light availability to the stream community, which not only increases the potential for primary producers (Sabater et al., 1998), but also increases the summer water temperature (Richardson, 2004) and changes the water quality and quantity (Knight and Bottorff, 1984). Many of the studies carried out to date have indicated that riparian zones provide some degree of protection (Richardson and Danehy, 2007). The most common approach to protect streams from agricultural or forestry practices is to use some form of riparian buffer to preserve some of the stream-riparian functions (Richardson, 2004). In this context, headwater streams are rather understudied, in part because they do not represent a management concern. However, intact headwater streams are crucial to the functioning of river systems (Meyer and Wallace, 2001) and they have been shown to be critical sites in river networks for processes such as nutrient uptake and retention (Peterson et al., 2001).

Catchment land use is often recognized as one of the most significant stressors of stream ecosystems. There are several principal mechanisms by which land use influences stream ecosystems: sedimentation, nutrient enrichment, contaminant pollution, riparian disturbance and hydrologic alterations (Allan, 2004). Thus different land use patterns lead to changes in water chemistry (Johnson et al., 1997; Ometo et al., 2000), hydrology and physical habitat conditions (Dunne and Leopold, 1978; Roth et al., 1996), which eventually decrease the biological integrity of streams. Despite the abundance of literature on the effects of land use on stream ecosystems (Leland and Porter, 2000; Pan et al., 2004; Newall and Walsh, 2005; Binckley et al., 2010; Studinski et al., 2012), quantifying the relationships between land use and the biological integrity of these habitats remains challenging. Headwater streams are particularly vulnerable to changing land use and non-point source pollutants, as small-order streams have a greater contribution of watershed area to stream area compared with larger streams (Selby et al., 1985). "They may experience greater nutrient inputs than larger streams owing to atmospheric deposition, saturation of terrestrial ecosystems, or mobilization from soils from the surrounding catchment" (Greenwood and Rosemond, 2005, see also Selby et al., 1985).

Stream periphyton is, contrary to secondary producers, directly influenced by changes related to light and nutrients availability. In headwaters, the benthic algal communities are typically dominated by diatoms (Cantonati, 1998; Greenwood and Rosemond, 2005; Danehy et al., 2007; Niedermayr and Schagerl, 2010). Benthic diatoms have long been recognized as reliable indicators of organic pollution, eutrophication and general pollution (Van Dam et al., 1994) and could be therefore considered as the only applicable indicator among primary producers in headwaters to detect impacts of stream ecosystem alterations. In this context, the focus of our work was to evaluate whether the impact of land uses such as urbanization and pasture on headwater streams can be mitigated by an intact forested buffer zone and whether diatoms reflect this buffer effect. Since such land use practices are reported to lead to significant nutrient enrichments of river systems (Leland and Porter, 2000; Rhodes et al., 2001; Inwood et al., 2005), diatoms should sensitively reflect all related changes in the stream.

Benthic diatoms are seen as reliable indicators of the impacts of different land use practices on stream ecosystems (Pan et al., 2004; Newall and Walsh, 2005; Hering et al., 2006; Walker and Pan, 2006; Walsh and Wepener, 2009). Most commonly, the effect of land uses on diatom assemblages is related to specific water quality variables such as nutrient concentrations, pH (Zampella et al., 2007) or salinity (Blinn and Bailey, 2001). The majority of these studies are typically based on the calculation of different diatom indices of water quality, which have been developed to assess pollution in rivers (Coste in Cemagref, 1982; Kelly and Whitton, 1995; Coring et al., 1999; Rott et al., 1999, 2003). The diatom indices calculation is usually based on the specific sensitivity of species to general or specific pollution (or to nutrient enrichment in general) and the species abundance. Among the metrics, the Specific Polluosensitivity Index (IPS) (Coste in Cemagref, 1982) is currently the most common diatom-based metric applied to the ecological status assessment of running waters in Europe (Kelly et al., 2009). Compared to other diatom indices, IPS was developed from a large database and involves large number of diatom taxa in the calculation, whose ecological characteristics are being regularly updated based on recent data from the monitoring networks. However, the high number of species and their unstable and fast changing taxonomy, which results in different species concepts being adopted by different authors, brings the accuracy of purely diatom metric-based assessment into question. Therefore, another assessment approach was recently proposed, which classifies diatom genera into three diatom guilds (low profile, high profile, motile) based on their growth form and potential to tolerate nutrient limitation and physical disturbance (Passy, 2007) and is currently being tested (Berthon et al., 2011; Gottschalk and Kahlert, 2012; Rimet and Bouchez, 2012). The assignment to the different guilds not only refers to the tolerance of species to nutrient supply, but also provides information on the structure of the diatom biofilm and resistance to disturbance. The low profile guild is favored in nutrient-poor and high physical disturbance habitats; the high profile guild reaches a maximum in nutrient-rich sites and in conditions of low flow disturbance; and the motile guild increases along the nutrient gradients and decreases along the disturbance gradient (Passy, 2007).

In our study, we aimed to evaluate the indicative potential of epilithic diatoms in headwaters with different riparian cover and different degree of land use practices in the catchment and the buffer zone. The specific objectives were (1) to evaluate how much the differences in the riparian cover influence diatom communities in headwater streams with different land use areas; (2) whether the presence of riparian vegetation and forestry in the buffer zone of a stream might act as a barrier against the negative influence of land use in the catchment (urbanization, pasture and crop land) on benthic diatoms and (3) whether diatom indicators such as diatom guilds and the IPS index have comparable indicative power across different degrees of nutrient enrichment and disturbance. This was undertaken by elucidating how water chemistry is changed by different land use patterns in the upper catchment and the buffer zone, whether the presence of riparian vegetation influences these relationships and, subsequently, how the diatom community structure, the proportion among the diatom guilds and the IPS index reflect these changes and impacts on aquatic system. The relative importance of the effects of land uses in the upper catchment and the buffer zone on water chemistry and diatoms was explored.

## 2. Methods

### 2.1. Site Selection and Description

This research was conducted in the Attert, Ernz noire and Syre river basins in Luxembourg (Fig. 1). Four streams were selected in the western highlands eco-region of Luxembourg, with contrasting shading conditions and land use. The streams were selected to represent three different types of conditions depending on the anthropogenic impact and riparian cover: unimpacted forested (shaded) conditions, impacted forested (shaded) conditions and impacted open (unshaded) conditions. The Schwaartzbaach stream represented unimpacted forested conditions, it occurs in an intact forested area with no or minimal anthropogenic influence in the buffer zone and upper catchment. The Consdorferbaach stream represented impacted forested (shaded) conditions and it occurs in an intact forested area similar to the Schwaartzbaach, but with intensive land use in the upper catchment. The riparian vegetation cover of both forested streams is composed of native deciduous woody vegetation, leading to overall shading of 85–100% of the stream channel, depending on the daily period. The Sauerbaach and Hemeschbaach streams represented impacted open (unshaded) conditions; they occur in areas with intensive land use in