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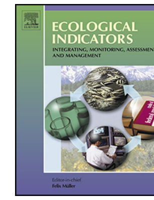

Algal assemblage responses to acid mine drainage and steel plant wastewater effluent up and downstream of pre and post wetland rehabilitation

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ABSTRACT

Algae give a time-integrated indication of specific water quality components and respond rapidly to water quality changes making them useful for biomonitoring purposes. Freshwater algae were employed to differentiate between water quality conditions up and downstream before and after wetland rehabilitation to determine the feasibility of wetland enlargement as a possible rehabilitation measure. Grootspruit valley bottom wetland, impacted by acid mine drainage, was severely degraded before restoration. Rehabilitation was done through redirection of water flow using concrete structures to enlarge the surface area by 9.4 ha. After wetland rehabilitation, pH values, suspended chlorophyll-*a* and alkalinity concentrations increased downstream, while electrical conductivity, sulphate, total suspended solids decreased up to 80%. Algae species diversity and richness corresponded with the improvement of water quality and also increased downstream after rehabilitation. Overall, results indicated an improvement in algal diversity and water quality after enlargement of the bottom wetland.

1. Introduction

Wetlands are highly sensitive ecosystems which make them vulnerable to degradation by land use activities (Danielson, 2002). Ecological wetland rehabilitation focuses on improving wetland ecosystem structure and function by improving the ecological integrity of the system (Zedler, 2000). This approach incorporates the physical, chemical and biological components of a wetland ecosystem. The most common and cost effective ecological approach is to reduce contaminants in to the system and to let the wetland system recover on its own. However, as in most wetland rehabilitation projects, a pre and post rehabilitation monitoring programme must be implemented by using indicator species to determine if ecological integrity has improved and continues to improve (Zedler, 2000). Although a variety of organisms can be employed as biological indicators in conjunction with physico-chemical parameters, algae were selected as biological indicators for determining the pre and post rehabilitation conditions of the Grootspruit valley bottom wetland. The latter was selected on the basis that (1) epilithic algae are stationary, and therefore directly indicative of the physico-chemical conditions of their immediate habitat (Stevenson and White, 1995; Oberholster et al., 2005); (2) epilithic algae have a short life cycle and will respond quickly to rehabilitation measures; and (3) algae are good indicators of acid mine drainage (AMD) and industrial effluent impacts in lentic systems for the purpose of rehabilitation (Oberholster et al., 2013; Chakraborty and Konar, 2002).

Sensitive species are systematically reduced or eliminated resulting in ecosystems characterised by low biodiversity and dominated by highly resistant and acidophilic biota due to the toxic effects of AMD (Oberholster et al., 2013). In these acidic environments one of the earliest and most reliable bioindicators of changes to algal communities is the proliferation of the filamentous green algal families (Oberholster et al., 2014a). In contrast, alkalinisation on algal communities has previously been studied, generally as part of lake experiments using lime to neutralise acid water (Hörnström, 1999). Under these conditions the reduction of the bloom forming filamentous green algal families and the increase of diatom species was reported (Jackson et al., 1990; Fairchild and Sherman, 1992). According to the data of earlier wetland surveys

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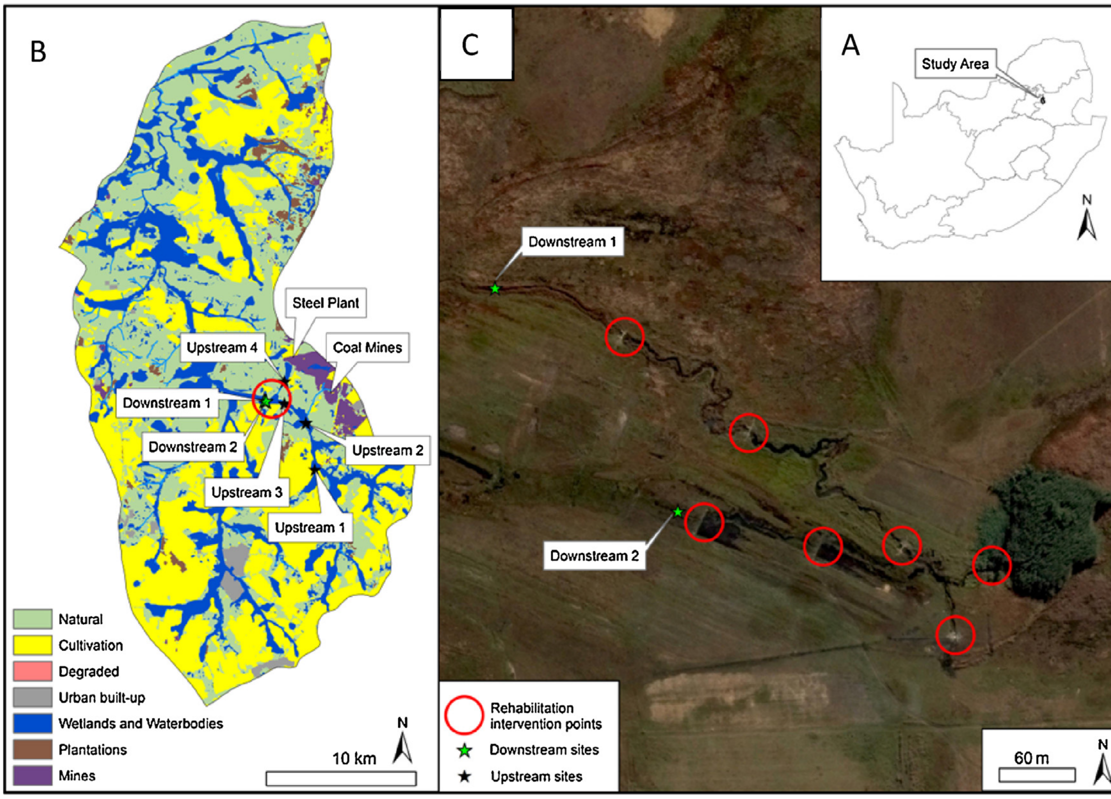

Fig. 1. Map of the study area in Mpumalanga, South Africa (A); up and downstream sampling sites of the Grootspruit valley bottom wetland (B), and the various intervention points constructed during the rehabilitation phase (C).

by Pan and Stevenson (1996) and Stevenson and Bahls (1999), pH is an important factor regulating algae composition in wetlands. Oberholster et al. (2014b) reported that benthic green filamentous algae can act as good indicators of wetland degradation by evaluating pH values and electrical conductivity in relationship with different types of wetlands. However, research on wetland algal communities as indicators of pH responses to wetland restoration efforts is limited. To the authors' knowledge, only two previous studies in literature tested the response of periphytic algal communities to a wide range of pH values in wetlands using a mesocosm experiments (Greenwood and Lowe, 2006; Wyatt and Stevenson, 2010). In the latter treatment studies the authors reported that high alkalinisation ($pH > 9$) significantly increased the algal community structure and l algal production in relationship with the control, while acidification ($pH < 5$) reduces algal diversity. A previous study by Chakraborty and Konar (2002) on the impact of steel plant effluent showed that it can severely hamper algae growth and diversity. Chakraborty and Konar (2002) reported in their study that effluent of steel plant waste in the Damor River, India, caused low transparency and low pH and high total suspended solids (TSS). The authors concluded from their study that discharge of steel plant waste caused habitat degradation resulting in ecological modification of phytoplankton communities.

August et al. (2002) stated that a natural wetland system has the ability to effectively remediate AMD by adaping to the low pH values and high metal concentrations. A long term study of 14 years conducted by Dean et al. (2013) on a AMD impacted natural wetland which included before and after drainage diversion showed that a severely AMD impacted system can substantially recover to a self-sustaining system once efficient remediation measures are implemented. The outcome of the latter study indicated that a combination of plant and microbial activities generated alkalinity that controls the pH of the water column. The authors also found in their study that the wetland caused metal retention regardless of the flow rate into the wetland, although the concentrations of metal removal by the wetland differ substantially under low and high flow conditions. This recovery occurrence from AMD impacts was also observed in other restored wetland studies using macroinvertebrates as indicators organisms (Gunn et al., 2010; Wiseman et al., 2004). The objectives of the current study were (a) to employ freshwater algae to differentiate between pre and post wetland rehabilitation conditions (b) and to determine if these algae can be used as reliable bioindicators for wetland enlargement rehabilitation measures.

2. Materials and methods

2.1. Study area

The Grootspruit valley bottom wetland (latitude −25.906480; longitude 29.052827) (Fig. 1), is situated in the Mpumalanga Province of South Africa. This valley bottom wetland covers an area of 135.3 ha and is heavily impacted by AMD from an abandoned underground coal mine upstream and effluent from an industrial steel plant. The wetland was originally classified as an unchannelled valley bottom wetland. However, due to the increase in flow in relationship with the decant water of the abounded coal mine above the wetland it change to a channelled valley bottom wetland over time. Although the wetland system was not originally acidic the inflow of AMD of the abounded mine upstream change it into an acidic system over time. Two separate streams flow into the channelled valley bottom wetland of which one contains AMD and the other wastewater effluent from an industrial steel plant (Fig. 1A). The water quality from the steel plant effluent was characterised by a high electric conductivity (EC), relatively low Al and Fe concentrations with a circumneutral pH and high turbidity. Higher water column temperature which is a characteristic of wastewater effluent from steel plants was not evident in comparison to