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# A diatom functional-based approach to assess changing environmental conditions in temporary depressional wetlands

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ABSTRACT

Functional-based assessments to identify the effects of human-induced disturbances on diatom communities are increasingly used. However, information on the response of functional groups to natural disturbances in temporary depressional wetlands is limited although important for the development of temporary wetland biological assessments. We assessed how diatom life-form and ecological guilds responded to a seasonal hydrological and hydrochemical gradient in three least human-disturbed, temporary depressional wetlands. We assigned species to their respective life-form and ecological guild groups and compared metric composition along the gradient. Overall, temporal variability in alkalinity and ionic composition, essentially $Na^+$, as well as hydrological factors, wetland depth and total relative evapotranspiration (ETo), were good predictors of diatom species and functional group composition. Low profile guilds dominated by pioneer life-forms showed the strongest relationship with higher disturbance levels (i.e. increasing $Na^+$, alkalinity with a decrease in depth). Similarly, the planktonic guild and tube-living, rosette and adnate life-forms dominated at higher disturbance levels whereas the high profile diatoms displayed the reverse trend. Our study shows the effectiveness of functional-based assessments beyond traditional species-based approaches for understanding and predicting community responses to temporal changes in environmental conditions. We also highlight the benefit of using both life-forms and ecological guilds where a broad set of metrics can enhance our understanding of the mechanisms relating diatom composition to environmental stressors and provide signs of underlying ecological processes.


## 1. Introduction

Over the past decade there have been increasing efforts to develop biological monitoring tools to assess the condition of wetlands in human-modified landscapes (e.g., U.S. EPA, 2002). In South Africa, although biological assessment techniques for river health assessments are well established (e.g., Dickens and Graham, 2002; Taylor et al., 2005), in the case of wetlands there is currently no definitive, well-developed method for assessing ecological condition. The need to develop wetland condition assessment methods is urgent, particularly in wetland rich areas such as the Mpumalanga Province where mining has contributed to substantial loss and degradation of depressional wetlands (Riato et al., 2014). Such activities have modified the surface water hydrology and hydrochemistry of temporary depressional wetlands to varying degrees, and in some cases has resulted in extreme alkalization, salinisation and permanent inundation in what was previously a fresh, ephemeral system.

Numerous studies have demonstrated the robustness of diatoms as a tool to assess the ecological status of shallow lakes and wetlands (reviews in Bennion et al., 2010; Gaiser and Rühland, 2010). Diatom-based indices have been developed to assess pollution in shallow systems, particularly in Europe and North America (e.g., Kelly et al., 2007; Lane and Brown, 2007; Stenger-Kovács et al., 2007). However, diatom-indices require species level identification which can be challenging due to the large diversity of species

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included in these indices and the continual taxonomical changes (Gottschalk and Kahlert, 2012). The presence of species complexes that are difficult to identify using standard taxonomic techniques constitutes an additional problem particularly when the finest taxonomic accuracy is required by the quality indices (B-Béres et al., 2014). Moreover, the suitability of these indices can be limited, since most diatom indices derive their calculations based on species distributions found in specific regions and thus are not broadly applicable (Stenger-Kovács et al., 2007).

Rimet and Bouchez (2012a) demonstrated the robustness of using a broader taxonomic resolution in bioassessments. For this reason, the use of trait-derived functional groups may be useful for wetland assessments, particularly in South Africa, where wetland diatom flora is poorly described, thus, taxonomic information required for species-level identifications is lacking. Moreover, the use of functional groups is likely to provide a greater understanding of the role by which important environmental drivers influence diatom community structure (Lange et al., 2016).

The application of diatom functional groups (life-forms and ecological guilds), have become increasingly popular in ecological assessments over the past decade (Tapolczai et al., 2016), mostly in response to nutrient and pesticide contamination in lotic systems (e.g., Lavoie et al., 2010; Passy, 2007a,b; Rimet and Bouchez, 2011) and mesocosm experiments (e.g., Bayona et al., 2014; Morin et al., 2009). However, few studies have applied functional groups as a community measure for the ecological status in lakes (e.g., Gottschalk and Kahlert, 2012; Leira et al., 2015) and only one other study has proven their applicability in wetlands (nutrient rich ditches) (Goldenberg Vilar et al., 2014).

Given the urgent need to develop a bioassessment tool for assessing temporary depressional wetland conditions in the Mpumalanga Province, the main goal of this research was to determine whether diatom functional groups can be used as simple, effective and reliable indicators sensitive to changing environmental conditions in temporary depressional wetlands in the region. Establishing a reference condition of variation due to natural disturbances (e.g., seasonal fluctuations in both water-level and water chemistry) in temporary depressional wetlands using diatoms is necessary for further investigations of anthropogenic impacts. Thus, we examined three least human-disturbed temporary depressional wetlands during various stages of inundation in order to understand the natural effects of hydrological changes on the water chemical composition and its influence on functional groups. We focused on four aims: (a) to identify the most important physico-chemical parameters influencing the structure of diatom species communities; (b) to compare those with the physico-chemical parameters structuring the functional groups; (c) to examine temporal dynamics of functional groups along the hydrological and hydrochemical gradient; and (d) to identify the groups most responsive to changes along the gradient.

## 2. Materials and methods

### 2.1. Study area

The study area is located in the Bapsfontein region of the Gauteng Province of South Africa at an altitude of 1606 m asl. Three homogenous, temporary depressional wetlands (average depth <2 m) were selected in this area based on vegetation, conductivity, surrounding land-use and close proximity to one another (radius of 1 km) (Fig. 1). The study sites (S1, S2 and S3) were sampled once a month from March 2011 (period of high inundation) to September 2012 (drying out period). Supplementary Data Appendix S1 summarises the physico-chemical parameters distinguishing the sites


**Fig. 1.** Map of study area showing location of sites (S1, S2 and S3); inset shows study area location in South Africa.

S1, S2 and S3 (Table S1) and provides a detailed description of the local climatology.

### 2.2. Sampling and laboratory methods

We collected one sample of epiphytic diatoms from at least five submersed macrophyte stems of the same vegetation type (*Leersia hexandra*) at the deepest point in the basin centre (pelagic zone) at each site to ensure the comparability between water bodies as recommended by King et al. (2006). Macrophyte stems were snipped and placed into a zip lock bag with a small amount of distilled water; epiphytes were dislodged from all stems by shaking the samples for 2 min following Zimba and Hopson (1997) . Samples were returned to the laboratory where they were acid cleaned and mounted on microscope slides. We counted and identified 400 valves to the lowest feasible taxonomic level using standard European diatom floras (e.g., Krammer and Lange-Bertalot, 1986-1991; Lange-Bertalot et al., 2001; Lange-Bertalot, 2000-2002), several papers on the Southern African flora by Cholnoky, Schoeman and Archibald (e.g., Schoeman and Archibald, 1976-1980), and books and recent papers on *Gomphonema* taxonomy (e.g., Reichardt, 2015; Reichardt and Lange-Bertalot, 1999; Rose and Cox, 2014).

Diatom taxa were assigned to two types of functional groups a), life-forms and b), ecological guilds, in accordance with Passy (2007a,b) and Rimet and Bouchez (2012b) . The taxa assigned to the various life-form and ecological guild groups are listed in Table 1. A taxon can be assigned to more than one life-form group since certain taxa can have multiple life-forms throughout its life-cycle (Rimet and Bouchez, 2012b).

We adapted the functional groups to accommodate taxa identified in our study which were not mentioned in Rimet and Bouchez (2012b). A total of sixty-three diatom samples were analysed and 83 taxa were identified. We examined the seasonal patterns of the different functional groups based on their relative abundances in order to develop a more comprehensive understanding of temporal changes in biofilm structure and provide insight into the major parameters structuring group composition.

We sampled chemical and physical parameters at the same location and time as the diatom sampling. Water samples (1 L) were collected in an acid-cleaned, high-density polyethylene bottle and kept on ice during transportation to the laboratory. Samples were analysed for concentrations of biological oxygen demand (BOD), $NH_4^+$, total Kjeldahl nitrogen (TKN), $NO_3^-$, $NO_2^-$, P, $PO_4^{2-}$, total phosphate (TP), $Ca^{2+}$, $Mg^{2+}$, $Na^+$, $K^+$, $Cl^-$, $SO_4^{2-}$, dissolved organic