Limnologica 64 (2017) 11–19

Contents lists available at ScienceDirect

Limnologica

journal homepage: www.elsevier.com/locate/limno

Understanding factors structuring zooplankton and macroinvertebrate assemblages in ephemeral pans

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ARTICLE INFO

Keywords:
Zooplankton
Macroinvertebrates
Ephemeral pans
Endorheic
Community

ABSTRACT

Ephemeral aquatic ecosystems have a global distribution being most abundant in semi-arid and arid regions. Due to anthropogenic impacts threatening these environments, there is a need to understand various factors and processes structuring animal communities in these habitats. Macroinvertebrate and zooplankton assemblages were studied in different ephemeral (i.e. flood plain, large endorheic and small endorheic) pans in the south-eastern Lowveld of Zimbabwe in the wet season. Ten Cladoceran species, Calanoids and Cyclopoids taxa and thirty-three macroinvertebrate taxa were identified over the entire hydroperiod. Predator macroinvertebrates were the dominant taxa especially in endorheic pans. The pan categories differed significantly in both zooplankton and macroinvertebrates composition and richness, with zooplankton and macroinvertebrate taxa richness being high in flood plain pans. Conductivity, fish presence, hydroperiod, maximum depth, turbidity and vegetation cover played a major role in shaping both zooplankton and macroinvertebrate communities. The macroinvertebrate community assemblage reveals that small endorheic and flood plain pans represent extremes ends of the environmental gradient in the region while large endorheic pans represent an intermediate end.

1. Introduction

Understanding the processes and factors that structure communities in ecosystems has always been a primary objective in ecology (Alfonso et al., 2016). Ephemeral pools have a widespread distribution in all types of habitats but they are also an integral part of the landscape of dryland regions (Dalu et al., 2017a,b). In addition to their own intrinsic conservation value, these habitats have also contributed immensely to the understanding of ecological theory (De Meester et al., 2005). They are habitats to unique fauna that have evolved with their temporal dynamics and they also are habitat to other crustaceans that include the micro-zooplankton (e.g. Cladocera, Copepoda, Rotifera) and macroinvertebrates (De Meester et al., 2005; Suárez-Morales et al., 2015; Dalu et al., 2017a,b). In southern Africa, ephemeral pans commonly occur in semi-arid regions, with varying hydroperiod depending on the amount of rainfall.

The response of aquatic biota communities to variable habitat gradients has received attention in some studies (Stoks and McPeek, 2003; Block and Stoks, 2005). The biota in these ephemeral aquatic habitats is adapted to short hydroperiods but may experience stress if habitat duration is unpredictable (Williams, 1996). Several studies on ephemeral pools also show the importance of physico-chemical characteristics in structuring zooplankton (Hancock and Timms, 2002) and vegetation communities (Cilliers and Bredenkamp, 2003; Janecke et al., 2003; Wasserman et al., 2016a). The structure of macroinvertebate communities has also been shown to be influenced by the limnological environment (Lahr et al., 1999; Bird and Day, 2016).

Macroinvertebrate and zooplankton of temporary pools have been the subject of several studies aimed at understanding ecological processes in the southern Africa region which have included endorheic pans (Dalu et al., 2016; Wasserman et al., 2016a,b), temporary wetlands (De Roeck et al., 2005; Waterkeyn et al., 2008) and dry season pools of both small and large ephemeral rivers (Nhiwatiwa et al., 2009). Significant contributions to the macroinvertebrate and zooplankton of temporary habitats have also been made in other regions. The influence of hydroperiod, salinity gradients and habitat characteristics has all been subject of these studies (Lahr et al., 1999; Bird and Day, 2016). From these studies there is general agreement on the

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http://dx.doi.org/10.1016/j.limno.2017.04.003
Received 17 November 2016; Received in revised form 27 March 2017; Accepted 2 April 2017
Available online 12 April 2017
0075-9511/

importance of hydroperiod but other local habitat characteristics tend to vary from region to region.

The drying of ephemeral pans was generally thought to prevent the colonisation and persistence of many large predators such as fish, although some organism can tolerate desiccation (e.g. turbellarians, lungfish, killifish) or leave the pans when they about dry out (e.g. amphibians and insects) (Bohonak and Whiteman, 1999; Spencer et al., 1999). Predation is recognised as a strong community structuring agent in many communities through both consumptive and non-consumptive effects (Wasserman et al., 2016a,b). Some ephemeral pool studies have shown that invertebrate communities are vulnerable to predation by amphibians and other macroinvertebrate predators (Blaustein, 1998; Wasserman et al., 2016b).

In this study, we investigated ecological variables structuring macroinvertebrates and zooplankton communities in ephemeral pans differing in size, hydroperiod and connectivity with a permanent river. We assessed if there were differences in community structure between the pans and local habitat characteristics. We hypothesised that temporal variation in macroinvertebrate and zooplankton communities differed with the hydroperiod and anticipated that the community composition will be influenced by the pan duration. Therefore, an understanding of the macroinvertebrate and zooplankton communities over time might help us make the right and wise conservation decisions for the management and preservation of these fragile ephemeral habitats.

2. Materials and methods

2.1. Study area

The Save Valley Wildlife Conservancy is situated in the Lowveld region of Zimbabwe (Lat: −20.15 to −20.45, Lon: 32.1–32.6; Fig. 1).

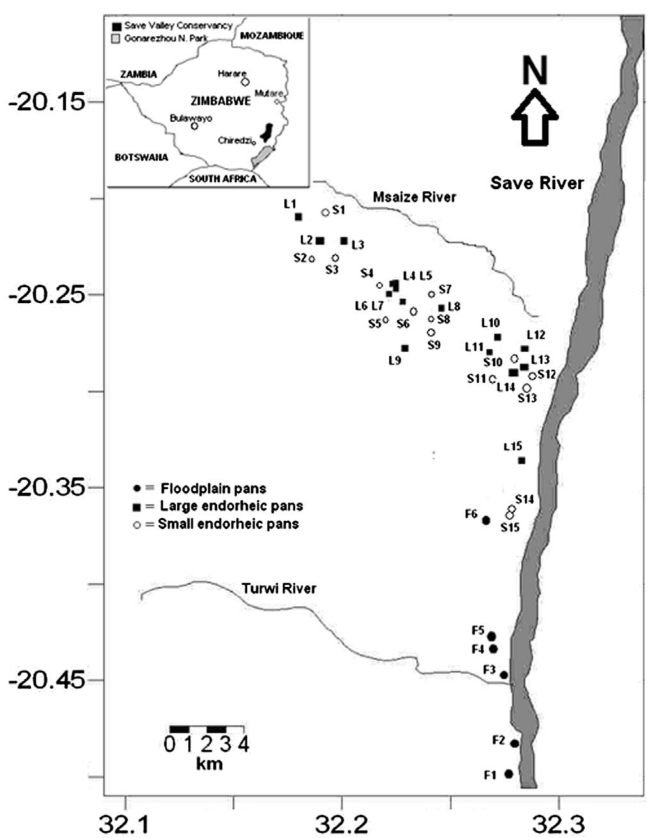

Fig. 1. Map of the study area, showing location of the study pans. Abbreviations: F – floodplain pan, L – large endorheic pan, S – small endorheic pan. Modified from Nhiwatiwa et al. (2009).

The mean annual rainfall is 582 mm and the mean rainfall during the sampling season was 285 mm (Department of Meteorological Services, Zimbabwe). Three types of pans were classified according to size (i.e. surface area and water depth) and hydroperiod: small (SP) and large (LP) endorheic and flood plain (FP) pans. Thirty-six pans were sampled every fortnight: 6 flood plain pans, 15 large endorheic pans and 15 small endorheic pans. Sampling date was done at the stipulated periods: T_1–end December; T_2–mid-January; T_3–end January; T_4–mid-February; T_5–end February; T_6–mid-March; T_7–end March; T_8–mid-April; T_9–end April and T_{10}–end June. Due to accessibility problems, flood plain pans were sampled once every month. During the rainfall season, the saturated basalt clays that characterise the floodplain are impassable by vehicle. Therefore, in order to reach the floodplain pans it was necessary to hike long distances in a very dangerous area that has black rhino, buffalo, elephants and lions. Because of safety considerations, sampling was restricted to once a month for floodplain pans. Eight sampling sites (i.e. 4 shallow and 4 deep areas) representative of all the habitats present in each pan type were selected, with the floodplain, large and small endorheic pans being sampled 6, 9 and 7 times, respectively.

Floodplain pans had substrate that was largely grey basaltic clays with a lot of dead organic material. Both small and large endorheic pans had clay loam substrates, with large endorheic pans having more clay compared to small pans. For small endorheic pans, vegetation cover was ~6% with a few pans covered with *Lemna minor* or *Mersalea* spp. Large endorheic pans on average had a vegetation cover of about 17%, dominated by *Nymphaea* spp., *Ceratophyllum* spp. and grass. Floodplain pans had consistently higher vegetation cover in comparison to endorheic pans and averaged 36%. Vegetation in floodplain pans comprised of *Chara* sp., *Ceratophyllum* spp., *Cyperus* spp., grass, *Lagarosiphon ilicifolius*, *Ludwigia ascedens*, *Juncus* sp., *Nymphaea* spp., *Potamogeton* spp., and *Polygonum senegalense*. All pans were not subject to human disturbance as they are located in a protected wildlife conservation area.

2.2. Environmental parameter measurements

For each pan, temperature (°C), dissolved oxygen (DO; mg L^{-1}) and pH were measured *in situ* at the middle of the pan using a multi-parameter meter (Model HQ 20, HACH LDO, Germany) and conductivity (μS cm^{-1}) using a conductivity meter (WTW LF330, Sigma Aldrich). Water samples for nutrient, turbidity, total suspended solids (TSS) and chlorophyll-*a* concentration were collected using a 10-L Ruttner water sampler (KC Denmark) at eight sampling points (i.e. 4 shallow and 4 deep areas) in each pan to form an integrated sample (n = 3) and stored on ice in the field. All water samples were processed within 8 h of collection in the field laboratory. Nutrients (i.e. ammonium, total nitrogen, total phosphorus, nitrates, COD, and reactive phosphorous) and turbidity were analysed using a spectrophotometer (HACH DR/2010, Colorado) following standards methods HACH (2007). Chlorophyll-*a* concentration was determined using the ethanol extraction method as described by Brönmark and Hansson (1998), and TSS was determined using standard methods by Gibbs (1967).

For each pan, maximum depth was measured with a calibrated stick along two perpendicular transects (n = 2) whereas maximum length and width were measured using a tape measure. Surface area was estimated as the surface area of an ellipse or multiple ellipses for more large pools. An assessment of total macrophyte vegetation cover was visually checked and scored using an arbitrary scale where: 0 (absent), 1 (< 25%), 2 (26–50%), 3 (51–75%), and 4 (76–100%) based on Killick (1978).

2.3. Invertebrate sampling

Zooplankton were sampled quantitatively by collecting a depth integrated water sample of 90 L from eight locations representative of