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The influence of biotope on invertebrate assemblages in lentic environments: A study of two perennial alkaline wetlands in the Western Cape, South Africa

Matthew S. Bird [a,*], Jenny A. Day [b], Heather L. Malan [c]

[a] DST/NRF Research Chair in Shallow Water Ecosystems, Nelson Mandela Metropolitan University, C/o Department of Zoology, P.O. Box 77000, Port Elizabeth 6031, South Africa
[b] Freshwater Research, Department of Biological Sciences, University of Cape Town, Private Bag, Rondebosch, South Africa
[c] Freshwater Research Centre, P.O. Box 43966, Scarborough, Cape Town, South Africa

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ABSTRACT

As a step towards the biological assessment of wetlands in South Africa, this study investigates the influence of biotope characteristics on the spatial distribution of aquatic invertebrates. The aim was to assess whether different wetland biotopes support significantly different invertebrate assemblages in terms of the composition and abundance of microcrustaceans and macroinvertebrate taxa. During October 2006, three different biotopes were sampled within Verlorenvlei and Wave's Edge wetlands (Western Cape, South Africa) using a long-handled sweep net. Composition and abundance of invertebrate assemblages were compared between and within sites for each of the wetlands. Assemblage composition generally differed among biotopes within each wetland, as revealed by cluster analysis and MDS plots. At Verlorenvlei, biotopes formed distinctive clusters with low site-specific variability. Assemblage composition at Wave's Edge revealed coarser groupings with clusters distinguishing between vegetated and non-vegetated biotopes only. Biotopes within each wetland differed significantly in terms of taxon richness, Shannon diversity and mean total invertebrate biomass ($g\ m^{-3}$), whilst mean total density ($ind\ m^{-3}$) differed only between biotopes in Verlorenvlei. Considerable shifts in invertebrate assemblage structure corresponded to differences in electrical conductivity among sites at Verlorenvlei. For large physico-chemically heterogeneous wetlands such as Verlorenvlei, it is suggested that smaller physico-chemically homogenous zones should be identified a priori and within these areas vegetated biotopes should be sampled over the broadest possible spatial scale, whilst open-water biotopes can be sampled more narrowly. For small, reasonably homogenous wetlands such as Wave's Edge, we suggest a less broad spatial representation of biotopes and instead one should concentrate on increasing the number of sample repetitions per site.

Introduction

Biological assessments (bioassessments) are designed to evaluate various facets of biological integrity (Teels and Adamus, 2002; Ollis et al., 2006). A variety of approaches using macroinvertebrates for the assessment and monitoring of water quality in lotic systems are available (for reviews, see Rosenberg and Resh, 1993; Barbour et al., 1999; Wright et al., 2000; Bonada et al., 2006; Ollis et al., 2006). Protocols using invertebrates to assess lentic wetlands are far less established than for rivers, although recently some momentum has been gained and there now exists a small body of literature describing cases where indices have been successfully developed for wetlands in specific areas (Chessman et al., 2002; Gernes and Helgen, 2002; Uzarski et al., 2004; Davis et al., 2006; Trigal et al., 2007; Solimini et al., 2008; Trigal et al., 2009). In South Africa, the South African Scoring System Version 5 (SASS5, Dickens and Graham, 2002) is a bioassessment procedure used to assess water quality in rivers. Although very effective in these environments, preliminary investigation suggests that SASS5 is not applicable in lentic systems (Bowd et al., 2006a; Bird et al., 2013). SASS5 relies on the scoring of diverse macroinvertebrate families, mostly of insects, whereas wetlands generally possess a lower diversity of macroinvertebrate taxa (Batzer et al., 1999) and are often dominated by an abundant microcrustacean fauna (Lemke and Benke, 2009) that cannot be rapidly assessed with the naked eye. Bioassessment techniques for wetlands thus need to be developed that cater for the

* Corresponding author. Tel.: +27 415042832.
E-mail address: matthew.bird@nmmu.ac.za (M.S. Bird).

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suite of invertebrates characterizing these wetlands. More specific understanding of the spatial dynamics of wetland invertebrate fauna in relation to different types of vegetated and non-vegetated habitats will help to establish sampling protocols that account for spatial heterogeneity of invertebrate assemblages in lentic wetland environments.

As a step towards developing a bioassessment protocol for lentic wetlands in South Africa, this study examines the spatial distribution of invertebrates in two such systems with specific reference to biotope characteristics. In order to assess the invertebrate biota of a wetland, a sufficient number of biotopes need to be selected to make the sample representative of the wetland. This requires identification of the wetland biotopes that support the greatest variety and production of aquatic invertebrates. In rivers, the distribution of macroinvertebrates appears to be mainly dependent on the particle size of the mineral component of the substrate, the quality and quantity of organic detritus, and on other factors such as food availability and current flow (Sheldon and Haick, 1981; Taniguchi et al., 2003; Dallas, 2007). In lentic environments, however, the habitat preference of macroinvertebrates seems to be primarily affected by various aspects of vegetation (Scheffer et al., 1984; Turner and Trexler, 1997; Tessier et al., 2004; Trigal-Dominguez et al., 2009). In this regard, the literature generally suggests an increase in diversity and abundance of aquatic invertebrates with increasing structural complexity of vegetated biotopes (Krecker, 1939; Beckett et al., 1992; Cardinale et al., 1998; Taniguchi et al., 2003; Lemke and Benke, 2009). Vegetated biotopes have been found to contain a higher diversity and abundance than non-vegetated (open-water) biotopes (Driver, 1977; Aiken, 1991; Van de Meutter et al., 2005), although there are exceptions to this generality (see Olson et al., 1995). Within the vegetated habitat, submerged aquatic vegetation has been reported by certain authors to support more diverse and abundant invertebrate assemblages than emergent vegetation, which has been attributed largely to the more complex architecture of submerged macrophyte species (Dvořak and Best, 1982; Lillie and Budd, 1992; Cheruvelil et al., 2002; Tessier et al., 2004). Conversely, de Klerk and Wepener (2011) reported higher diversity and richness of macroinvertebrates in marginal and emergent vegetation compared to submerged and floating-leaved vegetation for endorheic reed pans in Mpumalanga, South Africa.

Studies investigating biotope influences on lentic aquatic fauna have concentrated mostly on macroinvertebrates in large lake ecosystems dominated by open water. There is a general paucity of work that accounts for biotope influences in shallow vegetated wetlands or that considers microcrustaceans as an integral part of wetland assessment (Lemke and Benke, 2009). The overarching aim of this study is to assess whether different wetland biotopes support significantly different invertebrate assemblages in terms of the composition and abundance of both microcrustacean and macroinvertebrate taxa. Following the broader aquatic literature, we expected vegetated wetland biotopes to yield higher abundance, biomass and diversity of aquatic invertebrates than the unstructured open water habitat. Further, given the generally more complex structure of submerged than emergent aquatic vegetation, we hypothesized that submerged vegetation would support greater abundance, biomass and richness/diversity of aquatic invertebrates than emergent vegetation would, but that distinctions between these biotopes would be less apparent than between them and the open-water biotopes.

Methods

Study area

During October 2006 invertebrates were sampled from Verlorenvlei and Wave's Edge wetlands, which are situated in the Western Cape Province, South Africa (Fig. 1). Both systems are perennial and are characterized as alkaline freshwater coastal wetlands. They were chosen because they both contain a heterogeneous array of biotopes and are both relatively easily accessible.

Verlorenvlei (32°19′–32°29′ S, 18°20′–18°32′ E, Fig. 1a), a Ramsar Wetland of International Importance, is situated on the west coast of South Africa approximately 200 km north of Cape Town and 25 km south of the town of Lamberts Bay. The wetland extends inland in an easterly direction for a distance of approximately 13 km and has a maximum width of 1.5 km and a surface area of ca. 1500 ha. According to Ramsar criteria, the broader Verlorenvlei system is classified as a fresh oligotrophic lake bordered by marshland and reedswamp. This study focuses on habitats within the shallow marshland and reedswamp wetlands that fringe the open waterbody. While depths of up to 4 m are found in the open water, mean depth of the entire system is only 0.5 m (Martens and Davies, 1996). The inland component of Verlorenvlei is fresh to weakly oligohaline and this is the component sampled in the current study. Immediately adjacent to the sea the wetland can become temporarily mesohaline due to occasional exchanges with the ocean during winter storms. The Verlorenvlei catchment of approximately 1890 km^2, occurs in a transition zone between karroid and fynbos vegetation types with high terrestrial plant diversity. Verlorenvlei is fed directly by the Verlorenvlei River (Fig. 1a), which in turn drains several perennial tributaries (the Kruis, Hol, Krom Antonies and Bergvallei rivers) and numerous seasonal streams. The catchment is generally rural and undisturbed, although the Verlorenvlei River and its tributaries are abstracted for irrigation. The geology of the immediate catchment is heterogeneous, comprising Table Mountain Group sandstones, Tertiary to Recent sands and shales of the Malmesbury Group (Sinclair et al., 1986). Approximately 80% of the 250–300 mm of mean annual precipitation in the catchment falls during winter months (April-September), with summers being characteristically hot and dry, thus conforming to a mediterranean-climate regime (Sinclair et al., 1986; Martens and Davies, 1996).

Wave's Edge wetland (33°50′ S, 18°29′ E, Fig. 1b) is situated between the residential areas of Tableview and Milnerton in the northern sector of the Greater Cape Town Metropolitan Area, 15 km north-east of the city centre. The wetland is a perennial body of water that was an estuarine salt marsh of the Diep River until approximately 30 years ago when it was separated from surrounding waterbodies by a highway and became an isolated freshwater wetland. Mean depth of the wetland is 1 m and in its deepest parts is 2.5 m. It has a surface area of ca. 5 ha and lies immediately adjacent to a smaller un-named wetland and Rietvlei, a larger coastal lake of ca. 500 ha (Fig. 1b). The surface waters of these three waterbodies are completely separated from each other. Both Wave's Edge and Rietvlei fall within the Rietvlei Wetland Nature Reserve and are surrounded by urban areas, receiving relatively high nutrient input from the surrounding catchment. As in the case of Verlorenvlei, the area has a strong peak in rainfall during the winter months, although the climate is wetter, with mean annual precipitation in the area of 575 mm (Rebelo et al., 2006).

Sampling protocol

Three biotopes (emergent vegetation, submerged vegetation and open-water, Table 1) were sampled within each of the two wetlands using a square-framed, long-handled sweep net with a 23.5 cm mouth and 80 μm mesh. The general literature suggests that sweep-net sampling of shallow wetlands is the most effective sampling method where the goal is comparing invertebrate assemblage composition between biotopes and between wetlands (Cheal et al., 1993; Turner and Trexler, 1997; García-Criado and Trigal,