Journal of Arid Environments 141 (2017) 34–39

Contents lists available at ScienceDirect

Journal of Arid Environments

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

Perched wetlands: An explanation to wetland formation in semi-arid areas

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ARTICLE INFO

Article history:
Received 17 October 2016
Received in revised form
8 February 2017
Accepted 15 February 2017
Available online 24 February 2017

Keywords:
Calcrete
Dense clay layer
Duricrust
Impermeable sub-surface lens
Precipitation-fed wetland
Soil core

ABSTRACT

This research demonstrates the importance of "perches", a hard, impermeable sub-surface layer, for ephemeral wetland development in a semi-arid area. Over 1700 wetlands were identified in the Nelson Mandela Bay Municipality (NMBM), Eastern Cape, South Africa. The average wetland density in the Municipality is approximately nine wetlands per 10 km^2. This density is high considering the climate of the NMBM, where annual evapotranspiration rates are approximately three times higher (1800 mm) than the average annual rainfall (613 mm). The NMBM is diverse in terms of its climate, vegetation types, geomorphology and underlying geology. This environmental diversity has resulted in a range of wetland types. Previous research in the Municipality has indicated that the majority of these systems are precipitation driven, with minimal groundwater input. Therefore, other environmental processes facilitate the formation of wetlands. For this study, data from 46 wetland sites were used that were situated across the different environments in the NMBM (geology, climate etc.). Thirty-four wetlands were perched, and were from all three of the different wetland types studied: depressions, seeps and wetland flats. A dense clay layer was found at 14 sites, across different geological and sediment types. Calcrete lenses were recorded at seven sites that were associated with aeolian deposits. A shallow bedrock layer was also observed at nine sites on quartzitic sandstones of the Peninsula Formation. In conclusion, this study has highlighted that perches are key for wetland development in some semi-arid areas.

1. Introduction

This paper aims to explain how wetlands can be prevalent in a semi-arid area due to the formation of different types of "perches", a hard, impermeable sub-surface layer, on which a wetland can form. Semi-arid climates are defined as areas that have a low average annual precipitation, and an evapotranspiration rate that is at least 1.5 times higher, with a resulting aridity score of less than 0.65 (United Nations Environmental Programme, 2009). South Africa (SA) is primarily a semi-arid country, with limited water resources (Faramarzi et al., 2013). Wetlands form a critical component of water resources, found at the interface between aquatic and terrestrial environments, as well as between surface and groundwater systems (Keddy, 2010).

In semi-arid climates, such as SA, wetlands are predominantly ephemeral (non-permanent) in nature. These systems can be inundated ("wet") for days to years, depending on the geomorphological and climate setting of the system. However, as these systems are not always recognisable during the dry season (Day et al., 2010), they tend to be degraded or destroyed, without knowledge that they even existed (Bowen et al., 2010). In several catchments in SA, it is thought that over 50% of wetlands have already been eradicated (Department of Water Affairs and Forestry, 2005). It is, therefore, imperative that these ephemeral wetlands that occur in semi-arid areas are understood and sustainably managed to prevent further loss.

In addition, there are important processes associated with the functioning of wetland ecosystems including water movement, sediment distribution, nutrient storage and energy transfer, as well as distribution patterns of plants and animals (Cook and Hauer, 2007). As a result of the ephemeral nature of these systems, there

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http://dx.doi.org/10.1016/j.jaridenv.2017.02.004
0140-1963/

often are often more-diverse plant and animal communities that have adapted to the periodic desiccation cycles (Brinson and Malvárez, 2002).

Inundation in precipitation-fed systems are facilitated by a series of rainfall events where the amount of soil water gradually increases (Euliss et al., 2004). As the local water table is raised, the rate of infiltration slows down, eventually reversing the direction of flow and allowing the wetland to inundate (Euliss et al., 2004). Precipitation is known to drive many ephemeral systems in semi-arid areas such as vernal pools, some prairie potholes in the USA, and gilgais in Australia (Roshier et al., 2001; Leibowitz and Vining, 2003; Winter and LaBaugh, 2003; Zedler, 2003).

The biodiversity, hydrology, morphology of these systems, therefore, highlights the importance of understanding the underlying processes, such as perch formation, that drive ephemeral systems in semi-arid environments.

The study area is situated in the Eastern Cape, in SA (Fig. 1). The Nelson Mandela Bay Municipality (NMBM) is located in a semi-arid region that receives an average of 613 mm of aseasonal rainfall per year (data from South African Weather Service (2014)). The rainfall ranges between 420 mm in the north and 690 mm in the extreme southern parts of the Municipality (Fig. 1). Evapotranspiration rates are much higher, ranging between 1600 and 2000 mm per annum (Schulze, 2007). Previous studies carried out in the NMBM revealed an average density of about nine wetlands per 10 km^2 and over 1700 non-fluvial wetlands that are mostly ephemeral and small (see Schael et al. (2015) and Melly (2016)). These wetlands consisted of the six non-fluvial hydrogeomorphic (HGM) wetland types: depressions, seeps, wetland flats, floodplain wetlands, and channelled and unchannelled valley bottom wetlands (Schael et al., 2015), as defined in the SA wetland classification system (see Ollis et al. (2013)). Depressions, seeps and wetland flats were the three predominant HGM types in the NMBM, and were the focus of field studies.

The NMBM is diverse in its climate, vegetation and geomorphological features. This has resulted in a wide range of wetland types that are comprised of different hydrogeomorphic (HGM) units that have various sources of water (e.g. precipitation, overland flow, through flow or groundwater flow) (Table 1). The surface geology of the NMBM is also varied and has implications for the distribution, geomorphology and hydrology of the wetlands. The Municipality is underlain with quartzites from the Gamtoos and the Table Mountain Group (TMG) deposits. The TMG is superseded by formations in the Bokkeveld Group, which is mainly comprised of argillaceous material. Sandstones and mudstones of the Uitenhage Group supersede these groups. Semi-consolidated calcareous sandstones, sandy limestones and alluvial gravels of the younger Algoa Group, are also present. These recent deposits, as well as the unconsolidated quaternary aeolian deposits, comprise the surface geology in the NMBM (Maud, 1998). As a whole, erodible sandstone

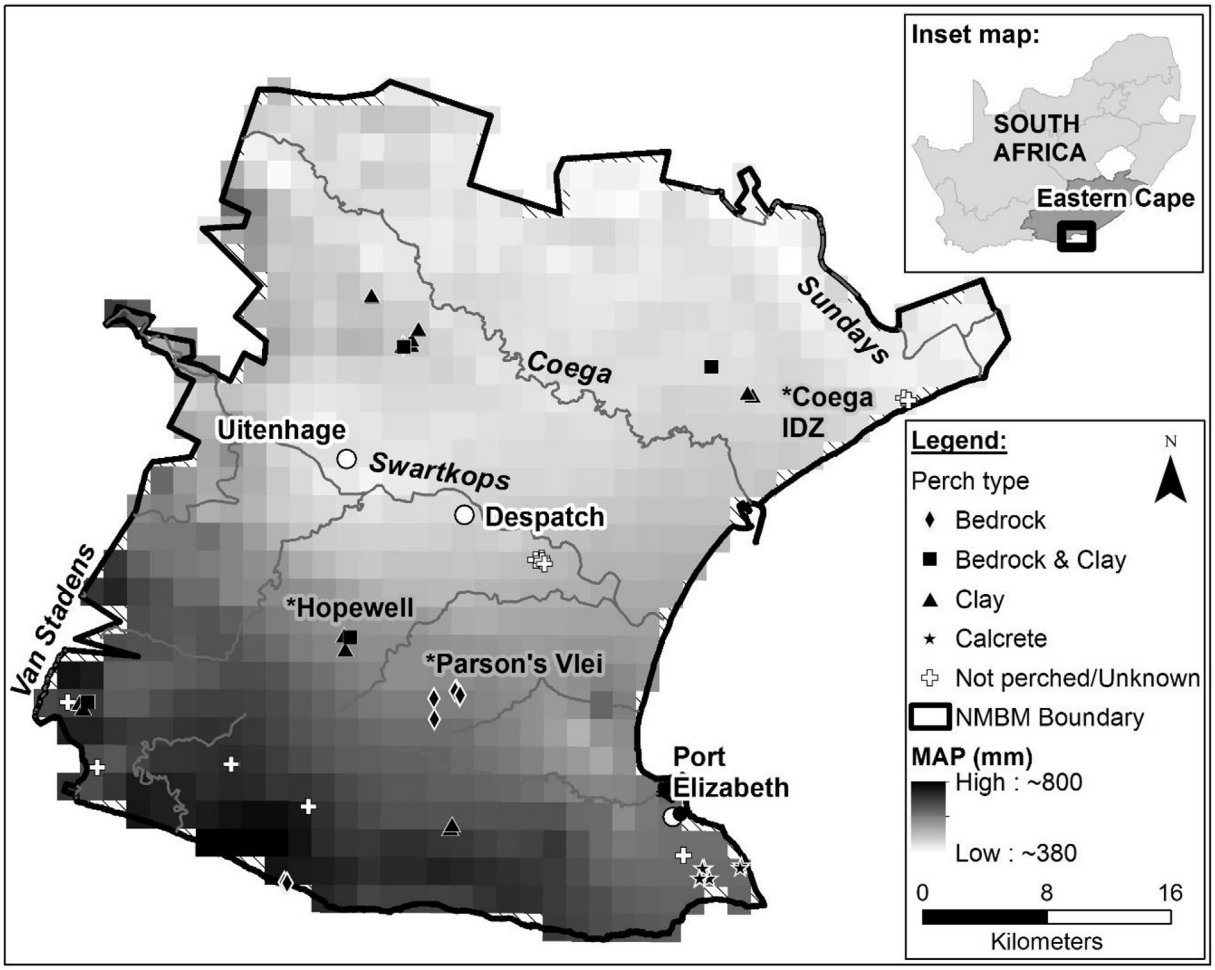

Fig. 1. The Nelson Mandela Bay Municipality (NMBM) study area. The 34 perched wetland sites identified were grouped into 4 categories, as labelled. Mean annual precipitation (MAP) increases from north to south. Port Elizabeth, Uitenhage and Despatch are the three main developed areas in the NMBM. Places denoted with an asterisk (*) are commented on in the text. Cross-hatches depict areas with no-data.