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The distribution of salt marsh macrophyte species in relation to physicochemical variables

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ABSTRACT

The aim of this study was to explore how estuarine salt marsh macrophytes are distributed in relation to physicochemical variables. This information was examined to determine whether macrophyte species are associated with a specific range of physicochemical variables and so could be used as bioindicators. The distribution of eleven macrophyte species in fourteen estuaries across the South African temperate coast was assessed in relation to sediment (moisture content, organic content, electrical conductivity, pH and redox potential) and groundwater (electrical conductivity, salinity and depth of the groundwater) variables. A univariate and multivariate approach showed that common salt marsh species were poor bioindicators as they occurred over a broad range of values across the measured physicochemical variables (i.e. *Bassia diffusa*, *Juncus kraussii*, *Sarcocornia pillansii*, *Sarcocornia tegetaria* and *Sporobolus virginicus*). It is therefore suggested that rare species (*Sarcocornia capensis*, *Frankenia pulverulenta*, *Poeciolepis ficoidea*, *S. decumbens*, *Plantago carnosa*, *Triglochin elongata*, *Spergularia media*, *Suaeda fruticosa and S. inflata*) be studied further to establish relationships with physicochemical variables as these may be useful indicators to monitor responses to sea level and other environmental changes. This study provides useful data on the ecological requirements of species and habitats in response to diverse physiochemical conditions across various estuaries spanning a regional scale.

1. Introduction

Salt marsh zonation is primarily influenced by temporal and spatial edaphic gradients as well as biotic interactions (Rogel et al., 2000; Bertness and Ewanchuk, 2002). The lower limits of these zones are set by tolerance to physical factors (high salinity and tidal inundation) and the upper limits by competition (Emery et al., 2001; Pennings and Moore, 2001; He and Bertness, 2014). The most important abiotic factors that delimit both the small and large scale distributions of coastal and inland saline habitats are salinity and water availability (Pennings and Callaway, 1992; Sanchez et al., 1998). Soil moisture is generally the limiting factor for the growth of xerohalophytes (drought adapted salt-tolerant species) (Riehl and Ungar, 1982), and in many systems it is determined by the depth to the water table (e.g. Bornman et al., 2008). According to Zedler et al. (1986), sediment physiochemistry in salt marshes is important because of the extreme conditions in these ecosystems and the substantial changes in both physical and chemical properties. Other important factors to measure and monitor include flooding (frequency and depth), nutrients, groundwater characteristics, organic matter, moisture content, sediment texture, as well as water potential gradients. The persistence of coastal salt marshes is influenced by adequate freshwater input and tidal exchange. Freshwater dilutes sediment salinity, thereby preventing dry, hypersaline conditions that inhibit macrophyte germination and growth (Adams and Bate, 1994).

Surface elevation influences the extent, period, and frequency of marsh inundation as well as physicochemical variables such as sediment moisture content, organic content, redox potential and salinity (Pennings and Callaway, 1992; Cacador et al., 2007; González-Alcaraz et al., 2014). Previous studies have predominantly focused on the salt marsh community composition, structure, and function at individual sites; very few place these factors into the context of larger-scale geography such as regions or latitude. McCall and Pennings (2012) investigated the latitudinal variation in salt marsh structure and function along the Atlantic Gulf coast. They found that sediment organic and moisture content were different between low and high rainfall regions. Similar studies by Bertness and Ewanchuk (2002) and Pennings et al. (2005) cautioned against generalized trends based on limited geographic sampling, as interactions among salt marsh plants may vary within and across estuarine systems due to differences in abiotic conditions and differences in community composition. Furthermore, most research on the influence of physicochemical variables has been conducted on a limited set of variables, or for one or two species within a few sites (e.g. González-Alcaraz et al., 2014). Rogel et al. (2000) suggested that a broader approach is needed to determine common physicochemical characteristics associated with specific plant assemblages. This will allow for the detection of shifts of species and species assemblages under environmental changes. It is expected that effects

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of climate change, particularly sea level rise, will lead to large-scale shifts in communities and within estuaries, as well as geographic shifts in vegetation types (Wasson et al., 2013). Associated with sea level rise is increased salinity penetration and inundation frequency, which are often co-determinants of zonation of salt marsh species. Furthermore, increases in groundwater and sediment salinity can lead to extirpation of species because migration into less saline lower tidal zones is not possible (Semeniuk, 2013; Wasson et al., 2013). Predicting the combined effects of these climate change variables at broad geographical scales on habitat area, fragmentation, and connectivity is required to inform management and ensure the preservation of healthy, functioning and intact ecosystems (Tabot and Adams, 2013).

Ecological niche theory posits that a set of physiochemical and biotic gradients affects the distribution of all species, and for each gradient there are thresholds between which the species can survive (Grime, 1979). In ecological studies, two niche parameters are frequently measured: niche breadth and niche overlap. Russell et al. (1985) found that niche overlaps in salt marsh were significantly smaller in marshes with more diverse vegetation; most species also had lower niche breadths with increased diversity. This suggests that competition is a likely driving factor influencing species niche dynamics in salt marshes. In contrast, Guo et al. (2015) demonstrated that plant community structure in salt marshes is influenced by both niche-based selection and stochastic processes, but that the relative influence of these two types of processes varies across estuarine landscapes.

The aim of this study was to determine the distribution of estuarine macrophytes relative to physicochemical variables. Data were explored to see if macrophyte species are associated with specific ranges of physicochemical variables. Plant distribution responds to changes in the soil–water conditions, and therefore monitoring of vegetation has been proposed as an effective tool to detect environmental impacts in wetlands (González-Alcaraz et al., 2014), and this likely also applies to salt marshes. The understanding of the response of macrophytes to various variables can thus contribute to monitoring protocols.

2. Materials and methods

2.1. Regional sampling of estuaries

Data were collated from completed MSc and PhD theses: Schmidt (MSc, 2013, Swartkops, Kromme, and Knysna estuaries) and Bezuidenhout (PhD, 2011, East Kleinemonde, Great Brak, Olifants, and Orange estuaries) (Fig. 1, Table 1A in supplementary material). Additional data were collected from the Olifants, Verlorenvlei, Berg, Uilkraals, Goukou, Gouritz, Keurbooms and Kabeljous estuaries in this study. The final dataset consisted of macrophyte composition and physicochemical parameters measured within fourteen estuaries. Additional information for these estuaries (i.e. estuary type, biogeographical region and habitat area) is provided in the supplementary material (Table 1B). The estuaries can be separated into two groups based on rainfall. For example, in the warm temperate region – which included the East Kleinemonde, Swartkops, Kabeljous and Kromme, Knysna and Great Brak estuaries – rainfall is approximately 400 and 700 mm per year (Day, 1981). In contrast the Orange, Olifants, Berg and Verlorenvlei estuaries are situated in the cool temperate region where the average annual precipitation is approximately 50 mm per year, with an average potential evaporation of over 3000 mm per year (Bornman et al., 2002).

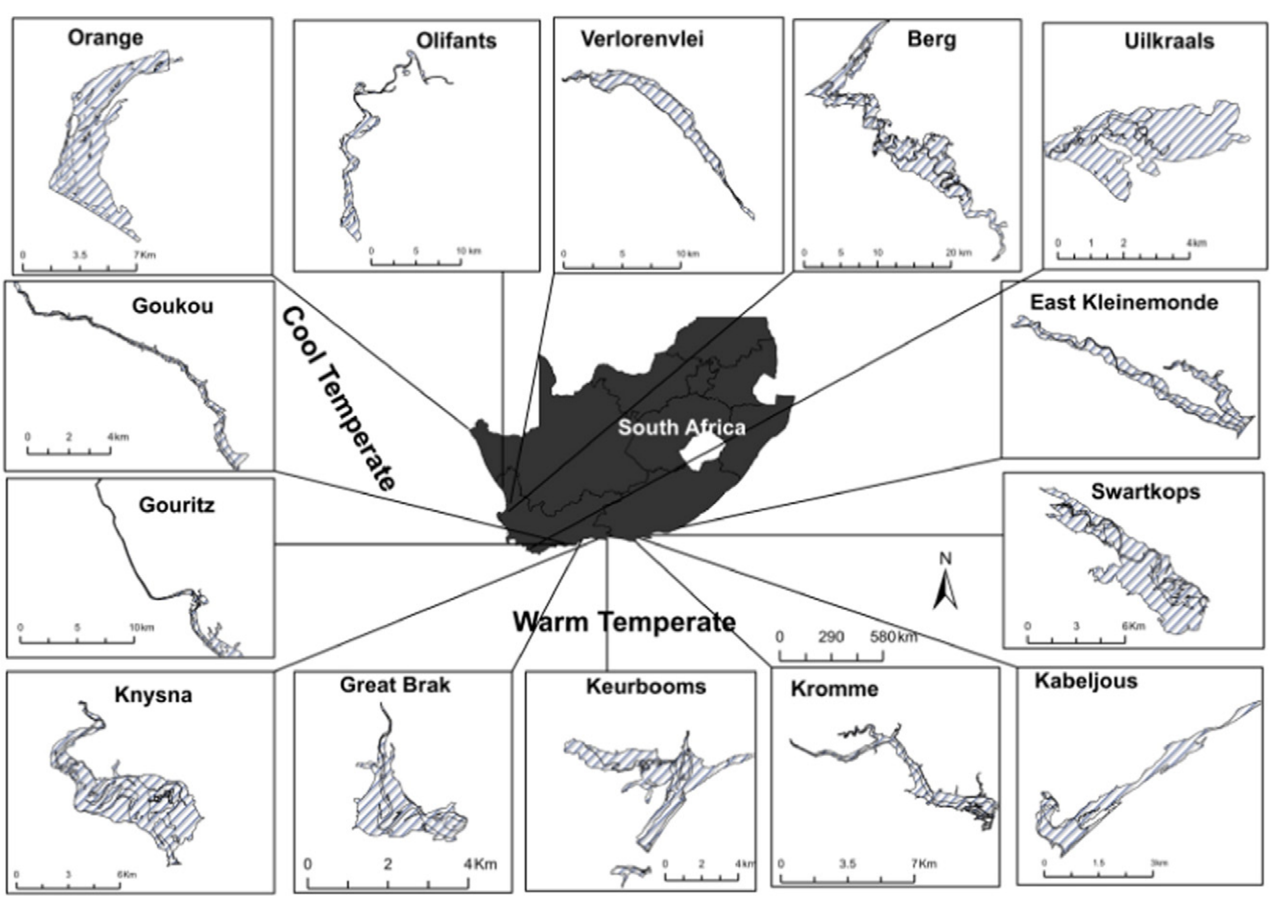

Fig. 1. Location of study site estuaries in South Africa.