South African Journal of Botany xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

South African Journal of Botany

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

Distribution of macrophyte species and habitats in South African estuaries

J.B. Adams [a,*], D. Veldkornet [a], P. Tabot [b,1]

[a] Department of Botany, Nelson Mandela Metropolitan University, PO Box 77000, Port Elizabeth 6031, South Africa
[b] Department of Agriculture, University of Buea, Cameroon

ARTICLE INFO

Article history:
Received 29 November 2015
Received in revised form 3 August 2016
Accepted 4 August 2016
Available online xxxx

Edited by T Riddin

Keywords:
Distribution
Estuary botanical database
Estuary habitat
Estuary type
Species richness

ABSTRACT

This study investigated the area coverage and species composition of different habitat types in all estuaries and bioclimatic regions along the coast of South Africa. Estuary habitat covers a total area of 95,657 ha. Reeds and sedges (14,732.6 ha) were the dominant habitat type overall. Supratidal salt marsh was dominant in the cool temperate region (4869.7 ha), intertidal salt marsh in the warm temperate region (2509 ha) and reeds and sedges in the subtropical region (10,484 ha). In the cool temperate, warm temperate and subtropical regions, the estuaries with the largest areas were the Berg (6799 ha), Knysna (2038.7 ha) and St Lucia estuaries (40,832.8 ha), respectively. The number of macrophyte species per estuary varied from one to 53. Macrophyte species richness was higher in estuaries of the cool and warm temperate zone than that in the subtropical zone. Macrophyte species are distributed in 47 families and the dominant families are the Cyperaceae (18), Chenopodiaceae (14), Juncaceae (5), while 15 other families had only one representative species. The number of species in temporarily open/closed estuaries (TOCEs) and permanently open estuaries (POEs) was higher than that found in other estuary types (river mouths, estuarine bays and lakes). Only *Juncus kraussii* and *Phragmites australis* occurred in more than half of South African estuaries. The data are collated in an estuary botanical database that can be accessed for monitoring and conservation planning purposes. These findings have already found application in the management of estuaries in South Africa, the National Biodiversity Assessment and the National Estuary Biodiversity Plan.

1. Introduction

The South African coastline is intersected by hundreds of rivers of varied sizes emptying into the Atlantic and Indian Oceans. Within the resulting estuaries, heterogeneity in physico-chemical properties results in several unique and important habitats for flora and fauna (Mucina et al., 2006). Estuary habitats are transitional tidal zones between land and sea occupied by algae, submerged macrophytes and emergent aquatic and terrestrial species that are tolerant of occasional flooding (Lubke and Van Wijk, 1988). Data on the area coverage and species composition of macrophyte habitats are used to determine the Estuarine Health Index for a particular estuary (DWAF, 2004). It is therefore important to have these data available to inform management. Furthermore a habitat rarity score was designed to take into consideration the number of habitats in an estuary, and the extent to which rare communities occur. This score, based on habitat area, is an essential component of the Estuary Importance Score which is used to rank estuaries in terms of their conservation importance (Turpie et al., 2002, 2012). However these data were not available for many individual estuaries. Where available, the dataset for the macrophyte species and habitat coverage was in most cases taken from the old "Green book" reports of CSIR for the CAPE estuaries and "The estuaries of Natal" for subtropical estuaries (Begg, 1978). These data are in most cases more than 30 years old; there have been substantial changes in estuaries since then and the habitat types have been reclassified.

The concept of classifying estuaries into different habitats was first articulated in Coetzee et al. (1997). They used the following plant community types: supratidal salt marsh, intertidal salt marsh, submerged macrophytes and reeds and sedges for Cape estuaries. Colloty et al. (1998) developed a modified estuary botanical importance rating for South Africa which then included swamp forest, mangroves, macroalgae and microalgae. The current nomenclature presented here arises from continuous refinement of mapping techniques and studies on zonation patterns (Veldkornet et al., 2015a, 2015b; Fernandes and Adams, in this issue). Hence estuaries were mapped into intertidal-, supratidal salt marsh, submerged macrophytes, reeds & sedges, mangroves, sand/mud banks, channel, rocks, swamp forest and macroalgae as unique habitats. Table 1 provides a description of these habitats for

* Corresponding author.
E-mail address: Janine.Adams@nmmu.ac.za (J.B. Adams).
[1] Current address.

http://dx.doi.org/10.1016/j.sajb.2016.08.001
0254-6299/

Table 1
Estuarine habitats recorded in the South African estuaries after Adams et al. (1999) with important taxa.

Habitat type	Defining features, typical/dominant species
Open surface water area	This is the habitat associated with the water column of an estuary and is measured as water surface area. Serves as a possible habitat for phytoplankton.
Sand and mud banks	This habitat provides a possible area for microphytobenthos to inhabit.
Macroalgae	These can be free floating or attached to rocks and other substrates. Filamentous macroalgae often form algal mats and increase in response to nutrient enrichment or calm sheltered conditions when the mouth of an estuary is closed. Typical genera include *Ulva* and *Cladophora*. Many marine species can get washed into an estuary and providing the salinity is high enough, can proliferate. These include *Codium*, *Caulerpa*, *Gracilaria* and *Polysiphonia*.
Submerged macrophytes	Plants that are rooted in both soft subtidal and low intertidal substrata and whose leaves and stems are completely submerged for most states of the tide. Submerged macrophytes tend to occur in permanently open estuaries, particularly eelgrass (*Zostera capensis*) whereas *Ruppia cirrhosa* prefers the less saline and sheltered conditions of estuarine lakes and temporarily open/closed estuaries. *Stuckenia pectinata* (ribbon weed, fennel pondweed) prefers fresher conditions (salinities below 10) and therefore occurs in closed systems or in the upper reaches of estuaries.
Salt marsh	Salt marsh plants show distinct zonation patterns along tidal inundation and salinity gradients. Zonation is well developed in estuaries with a large tidal range e.g. Berg, Knysna and Swartkops estuaries. Common genera are *Sarcocornia*, *Salicornia*, *Triglochin*, *Limonium* and *Juncus*. Halophytic grasses such as *Sporobolus virginicus* and *Paspalum* spp. are also present. Intertidal salt marsh occurs below mean high water spring and supratidal salt marsh above this. *Sarcocornia pillansii* is common in the supratidal zone and large stands can occur in estuaries such as the Olifants.
Reeds and sedges	Reeds, sedges and rushes are important in the freshwater and brackish zones of estuaries. Because they are often associated with freshwater input they can be used to identify freshwater seepage sites along estuaries. The dominant species are the common reed *Phragmites australis*, *Schoenoplectus scirpoides* and *Bolboschoenus maritimus*.
Mangroves	Mangroves are trees that establish in the intertidal zone in permanently open estuaries along the east coast of South Africa north of East London where water temperature is usually above 20 °C. The white mangrove *Avicennia marina* is the most abudant, followed by *Bruguiera gymnorrhiza* and then *Rhizophora mucronata*.
Floodplain	This is a mostly grassy area which occurs within the 5 m contour line. Also includes dune vegetation at the mouth and riparian vegetation along the middle and upper reaches of the estuary.

South African estuaries. The research presented here shows the current state of the different habitats in South African estuaries and serves as a baseline for subsequent monitoring, planning and management.

The same paucity of data also applies to macrophyte species occurrence in estuaries, mostly because of 1) the inability to identify estuary species as a result of the cryptic nature of morphological characters and 2) the general belief that estuaries have low species richness. Very few of the macrophyte species are endemic while others have a worldwide distribution. However, two recent publications by Steffen et al. (2010) and Köcke et al. (2010) showed that some *Sarcocornia* and *Triglochin* species are endemic to South Africa and some are threatened. Furthermore, South African estuaries are under significant development pressure as well as the ensuing threats of climate change leaving macrophyte species vulnerable to local extinction (Van Niekerk and Turpie, 2012).

Adams et al. (1999) estimated that salt marshes occupy approximately 17,000 ha in only 70 of 277 estuaries where they perform a number of important functions. Since then the extent of salt marsh and other estuarine habitat was collated from available data in Adams et al. (2012) which informed the National Biodiversity Assessment of 2011 (Van Niekerk and Turpie, 2012). The National Estuary Biodiversity Plan set conservation targets using the habitat area data. For each habitat type, 20% of the total area was prioritized for conservation whereas for mangrove and swamp forest, estuaries that had greater than 5 ha of these habitats were prioritized for conservation. Thus the data in the Estuary Botanical Database have already found application in management of estuaries in South Africa and it is for these reasons that the data are regularly collated and updated.

This research investigated the distribution of macrophyte species and habitats in different types of estuaries and across climatic zones. The classification of estuary types (Estuarine bays, Permanently open, River mouth, Estuarine lake, and Temporarily open/closed estuaries according to Whitfield, 1992) is based on physical characteristics which influence macrophyte species composition. In each bioclimatic region, it is possible that unique plant communities exist as a result of differential tolerance to the local and regional abiotic stressors. Yet within estuaries, habitat heterogeneity is important in determining species diversity (Nielsen et al., 2012). The west coast of South Africa is classified as the cool temperate zone. The warm temperate zone extends approximately from Cape Point to the Mbashe River in the Eastern Cape, and the subtropical zone is on the east coast (Harrison, 2004). This is based on seawater rather than air temperature.

The aims of this study were to 1) to determine the total area coverage and species composition of differing estuary habitats associated with different estuary types and bioclimatic regions, and 2) publish the estuary botanical database so that the information is available particularly for lesser known estuaries. This work therefore provides a cohesive framework for existing and new information on estuary habitat heterogeneity, using plant habitat types as a reference point and can be applied in various management and conservation scenarios.

2. Materials and methods

2.1. The estuary botanical database (excel file — supplementary data)

The original source for these data was Colloty (2000), and these have been updated from site visits, graduate research projects, ecological water requirement studies and any other initiatives that included macrophyte mapping and a detailed assessment of species composition. All data on macrophyte habitat area coverage and species were entered into the Estuary Botanical Database which is an Excel workbook consisting of three worksheets. The habitat cover worksheet contains each estuary, location, habitat area and human pressures such as extent of development. The species worksheet lists the presence of macrophyte species collected in 297 different estuaries. The habitat richness worksheet contains information on the number of estuary habitats in each estuary. An earlier version of the database was used by Turpie et al. (2002) and Turpie and Clark (2007) to determine the conservation and biodiversity importance of South Africa's estuaries. It was also used in the 2004 National Spatial Biodiversity Assessment (NSBA). The revised Botanical Database formed a component of the 2011 NBA estuaries dataset and has been updated regularly since then so that it could provide continuous input to the estuaries component of the National Biodiversity Assessment undertaken by the South African National Biodiversity Institute (SANBI).

2.2. Habitat area cover

The original source for the area cover data was from Colloty (2000) and Walker (2003). The data presented in this paper include recent updates on habitat distribution and area cover from a variety of sources described below. Despite these updates there are still only GIS vegetation maps available for 18% (53/297) of South Africa's estuaries. Ultimately, it is hoped that all the estuaries will be mapped, providing a basis for

Please cite this article as: Adams, J.B., et al., Distribution of macrophyte species and habitats in South African estuaries, South African Journal of Botany (2016), http://dx.doi.org/10.1016/j.sajb.2016.08.001