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Quantifying the loss of and changes in estuary habitats in the uMkhomazi and Mvoti estuaries, South Africa

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ABSTRACT

The Estuarine Health Index was applied to determine macrophyte health of the permanently open uMkhomazi Estuary and Mvoti River Mouth, KwaZulu-Natal. Macrophyte health was assessed in terms of the degree of similarity of species richness, abundance and community composition to reference condition (natural state prior to human influence). Changes over time in the area covered by different estuary habitats were assessed using available historical data and mapping of the earliest available aerial photographs together with field surveys and mapping in 2013. The floodplains of both estuaries have been transformed by sugarcane cultivation and colonisation by invasive alien plants, resulting in intact macrophyte habitats only occupying 60% of uMkhomazi and 40% of Mvoti Estuary. Reduced freshwater inflow and input of wastewater at Mvoti Estuary have led to reed encroachment (50% greater cover than natural) and spread of hygrophilous grasses into the open water. Macrophyte species richness in both estuaries was lower than previous botanical studies. Overall macrophyte health was poor with the uMkhomazi Estuary in a moderately modified state and Mvoti Estuary in a largely modified state.

1. Introduction

Humans have been utilising and modifying coastal environments for millennia resulting in a decline in water quality and biodiversity, loss of critical habitats, and an overall decrease in the quality of life for local inhabitants (Rick and Erlandson, 2009). The magnitude of these impacts suggests an urgent need to characterise the present condition of coastal environments. Qualitative data, however, is limited to the past few decades and some systems have been modified to such an extent that the natural condition of the system is not known (Zu Ermgassen et al., 2012). Understanding historical conditions provides a robust baseline for assessing change and modelling past ecosystem functions. This knowledge is imperative for guiding conservation and management plans, particularly in light of global change (Byrd et al., 2004). Most assessments of ecological health use historical conditions (reference or natural state) as the benchmark against which the present status of an ecosystem can be compared (Stoddard et al., 2006; Hawkins et al., 2010).

Establishing natural or reference condition is challenging as historical accounts are often brief and fragmented with anecdotal accounts rather than quantitative data (Zu Ermgassen et al., 2012). Almost no data exists for systems prior to their utilisation by man and thus reference conditions may need to be extrapolated from the historical data available. Historical ecology is therefore inductive and the interpretation of historical data is highly subjective (Swetnam et al., 1999). The accuracy of data can be improved by verifying with other sources and quantifying the data with present day observations or experiments. In some instances, particularly in northern hemisphere estuaries, the systems have been completely transformed to such an extent that they can only be managed towards a best attainable state and not natural condition. The Nhlabane Estuary in KwaZulu-Natal, is an example of such a system in South Africa. The construction of a barrage and subsequent water abstraction separated the estuary from the previously linked estuarine lake (DWAF, 2000).

Macrophytes respond to disturbance in aquatic ecosystems allowing them to be used as bioindicators of ecological condition (Mackay et al., 2010; Søndergaard et al., 2010). They respond to environmental stressors (such as changes in water-depth, turbidity, sediment deposition and nutrient enrichment) with changes in species richness, taxonomic composition and abundance (Pereira et al., 2012). Macrophyte habitats tend to follow distinct zonation patterns and are often ubiquitous across large geographic regions. Species can be relatively easily recorded in the field and their determination tends to not be time consuming or expensive. Their distribution and changes in area over time can be determined from aerial photographs using a geographic information system (GIS) (Turpie et al., 2012).

Macrophytes are one of the biotic indicators used to determine ecological health of aquatic ecosystems for both the EU Water Framework Directive (WFD) and the Estuarine Health Index (EHI) of South Africa. A number of macrophyte based assessments of ecological status are used in Europe including the German Trophic Index of Macrophytes (Schneider and Melzer, 2003), the French Biological Macrophyte Index

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(Haury et al., 2006) and the Ecological State Macrophyte Index (ESMI). ESMI assesses the ecological status of lakes based on macrophytes (Ciecierska and Kolada, 2014). Macrophyte condition is determined using the following parameters: number of plant communities, the proportion of each community in the total vegetation cover and macrophyte spatial colonisation patterns.

South Africa's EHI is a simple, robust and quantitative method for determining ecological health of estuaries using changes in abiotic and biotic components compared to reference conditions (Turpie et al., 2012). Reference conditions refer to the natural, pristine state of the system prior to human influence, roughly 100 years ago for South Africa estuaries, determined from available information and expert opinion. Three parameters are used to assess macrophyte health, namely: species richness, abundance and community composition. In both the ESMI and the EHI data are obtained from transects running perpendicular to the open water until the outer limit of macrophyte growth. Aquatic plants are identified through wading with rakes and all species identified are classified using the phytosociological approach. In South Africa the 5 m topographical contour is used as the lateral boundary of the estuary functional zone (EFZ) (SANBI, 2011). The status of nine macrophyte habitats within the EFZ is described, namely: open water, sand/mud banks, macroalgae, submerged macrophytes, reeds and sedges, salt marsh, reeds and sedges, swamp forest and mangroves.

Changes in macrophyte distribution and cover are determined from mapping aerial photographs (earliest available and most recent) in GIS. Ground truthing in the field is used to improve the accuracy of the vegetation maps produced. Species richness is measured as the loss in the average species richness expected during a sampling event. Abundance and community composition are calculated from the areas covered by the different macrophyte habitats for present and reference condition using a similarity index. In estuaries with salt marsh high confidence assessments of macrophyte health require permanent transects along an elevation gradient with measurements of percentage plant cover, salinity, water level, sediment moisture content and turbidity as well as measurements of depth to water table and ground water salinity. This is only done for the salt marsh habitat as conditions change in response to alterations in freshwater inflow particularly flooding.

The EHI has been successfully applied, at varying levels of determination, to 40% of estuaries in South Africa. This study applies the biotic health scoring of the EHI to macrophytes of two estuaries initiated as part of the classification of water resources for the Mvoti–Umzimkulu Water Management Area (WMA 11) in KwaZulu-Natal (KZN) (DWA, 2013). To date no study has described the application of the macrophyte method. The study presents the method for quantifying the loss and changes in estuary habitats for the permanently open uMkhomazi Estuary and the Mvoti River mouth, the sixth and third largest systems in WMA 11, respectively. The water resources of WMA 11 are increasingly stressed due to an accelerated rate of development and changing weather patterns resulting in the scarcity of water. Following a protracted drought KZN was formally declared as a disaster zone in 2014 (South African Government, 2015). Macrophyte health is dependent on prevailing environmental conditions, which are affected by freshwater inputs. Sugarcane cultivation, plantations, invasive alien plants (IAPs), sand mining and input of wastewater have impacted on the health of KZN estuaries (Forbes and Demetriades, 2008). The National Biodiversity Assessment described uMkhomazi Estuary as moderately modified (C Ecological Category) and the Mvoti Estuary as highly degraded ('D' EC) (Van Niekerk and Turpie, 2012).

2. Materials and methods

2.1. Study area

The permanently open uMkhomazi Estuary (30°12′03″S; 30°48′11″E, roughly 50 km south west of Durban with the suburb of Umkomaas situated on the south bank) and Mvoti River Mouth (29°24′03″S; 31°20′18″E discharging at Blythedale Beach roughly 80 km north of Durban) are located on the subtropical east coast of South Africa (Fig. 1). Almost all of the 64 estuaries comprising WMA 11 are temporarily open/closed systems, with uMkhomazi representing one of only two permanently open estuaries and Mvoti Estuary as the only river mouth. For the WMA both estuaries have large catchments—uMkhomazi *ca.* 4300 km^2 and Mvoti *ca.* 2700 km^2 of which nearly 20% and 60% of their respective catchments are composed of forest plantations and cultivation (sugarcane, commercial and subsistence farming) (DWA, 2014a,b; Fig. 1).

The mouth of both estuaries are considered the downstream boundaries and the R102 road bridge (30°10′25.64″S; 30°44′51.42″E) and N2 road bridges are considered the upstream boundaries of uMkhomazi and Mvoti estuaries, respectively. For both estuaries the lateral estuary boundary was the EFZ i.e. the 5 m contour above MSL along the banks. The national estuary shapefile of the EFZ is available online at www.bgis.sanbi.org. This delineates the area below in which most of the physical and biological processes in the estuaries occur.

Previous health assessments (Begg, 1978, 1984; Heydorn, 1986; Quinn and Whitfield, 1998; Harrison et al., 2000; Demetriades, 2007; Forbes and Demetriades, 2008; Van Niekerk and Turpie, 2012) have described both estuaries to be in poor condition. The poor health of the uMkhomazi Estuary has been attributed to siltation and waste from the upstream SAPPI SAICCOR paper mill factory and the removal and disturbance of riparian habitat for the construction of the associated railway and pipelines (Begg, 1978; Forbes and Demetriades, 2008). Van Niekerk and Turpie (2012) and Turpie et al. (2012) attributed the degraded condition of the Mvoti Estuary to a moderate reduction (30%) in flow and poor water quality because of input from the SAPPI SAICCOR factory, Gledhow Sugar Mill and the Stanger-Kwadukuza Waste Water Treatment Works (Swemmer, 2011). Estuarine habitat has been lost from both systems due to sugarcane cultivation, urban encroachment and sand mining activities (Quinn and Whitfield, 1998; Demetriades, 2007; Swemmer, 2011; Van Niekerk and Turpie, 2012).

2.2. Present distribution of macrophyte habitats

The distribution of the nine recognised macrophyte habitats within the EFZ of the estuaries was manually delineated using visual interpretation from 2013 orthorectified aerial photographs using ESRI™ ArcMap 10.2 (2013). Colour and physiognomy can be used to differentiate between macrophyte habitats in aerial photographs. For instance reed and sedge habitats appear as light brown areas with little differentiation. All aerial photographs used were obtained from the National Geo-spatial Information (previous Chief Directorate: Surveys and Mapping). (NGI, 2013a,b,c,d,e) and Emzemvelo KZN-Wildlife. The distribution of macrophyte habitats (identified from indicator species) was verified in the field with surveys by boat (uMkhomazi) and foot (Mvoti) along both banks of the estuaries. The estuaries were visited on 17 and 18 July 2013 and both systems were open at the time of sampling. Arcpad 10.1 loaded on Trimble Juno GPS was used to map the distribution of macrophyte habitats in the field. Developed or disturbed areas, for example where cultivation has previously been mapped, but no longer exists, within the EFZ of the estuaries were mapped as such. Terrestrial forest vegetation was broadly mapped as a coastal forest and was not distinguished into vegetation classes.

Species that could not be identified in the field were collected for identification at the Ward Herbarium, University of KwaZulu-Natal, and the Ria Olivier Herbarium, Nelson Mandela Metropolitan University. Species nomenclature followed that of Germishuizen et al. (2006) and threat status was determined from the Red List of South African Plants Version 2014.1. (SANBI, 2014). IAPs were identified from the updated National Environmental Management: Biodiversity (NEMBA, Act 10 of 2004) (DEA, 2014).

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