# Not so pristine – characterising the physico-chemical conditions of an undescribed temporarily open/closed estuary

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## Abstract

A rapid ecological water requirement study of the Department of Water Affairs in 2009 classified the Goukamma Estuary as largely natural with few modifications, i.e., in an A/B state. However this detailed 13-month study showed that the estuary is impacted. Salinity stratification and hypoxic conditions (dissolved oxygen (DO) < 3 mg·ℓ$^{-1}$) were measured during both open and closed mouth states. The Goukamma Estuary is a blackwater system and in its natural state is expected to be nutrient poor. However high nutrient concentrations were measured in the middle and upper reaches of the estuary, adjacent to cattle farms. Nutrient concentrations represented mesotrophic (DIN > 500 µg·ℓ$^{-1}$) to eutrophic conditions (DIP > 25 µg·ℓ$^{-1}$). Nutrient input stimulated microalgae to attain a high biomass, ranging between 0.3 and 112 µg·ℓ$^{-1}$ (average 7.7 ± 1.3 µg·ℓ$^{-1}$) and 0.8 and 289 µg·ℓ$^{-1}$ (average 21.1 ± 4.4 µg·ℓ$^{-1}$) during the open and closed mouth states, respectively. Exacerbated by natural salinity stratification which effectively limits oxygenation of the water column, unnaturally high nutrient concentrations, microalgal blooms and coinciding organic loads all indicate poor water quality of the Goukamma Estuary. This research showed that detailed studies involving field measurements of water quality are required before the present health status of an estuary can be assessed.

**Keywords**: Temporarily open/closed estuaries, blackwater system, water quality, stratification, hypoxia, DIN, DIP, microalgae biomass

## INTRODUCTION

Situated at the interface between fresh- and marine waters, estuaries are among the most biologically productive ecosystems in the world and are of great ecological and economic importance (Turpie and Clarke, 2007; Shimmield 2012). Yet, these water bodies are becoming some of the world's most threatened habitats (Elsdon et al., 2009). Characterised by their natural complexity, estuaries face degradation due to human-induced alterations to their dynamic variability (De Villiers and Thiart, 2007; McQuatters-Gollop et al., 2009; Robertson and Funnell, 2012). Nutrient over-enrichment is considered to be one of the most serious human-induced impacts on estuaries (Heisler et al., 2008; Costa et al. 2009; Robertson and Funnell, 2012).

Nutrient over-enrichment is mainly associated with the input of excessive amounts of nutrients, which leads to a build-up of organic material. During bacteriological decomposition of the latter, oxygen demand in the water column exceeds the oxygen supply and typically results in oxygen-deficient conditions, termed hypoxia (DO < 3 mg·ℓ$^{-1}$) and anoxia (DO = 0 mg·ℓ$^{-1}$) (McQuatters-Gollop et al., 2009; Shimmield, 2012; Cowie and Woulds, 2012). Hypoxia is directly linked to a degraded water quality, which holds numerous detrimental effects for the biota of the system (Barton and Sherwood, 2004; De Villiers and Thiart, 2007; Turpie and Clarke, 2007; Becker et al., 2009).

On the other hand, hypoxia can also be a natural phenomenon. In estuaries, water circulation processes (e.g. mixing, flushing and retention times) are responsible for regulating overall water quality characteristics (Snow and Taljaard, 2007; Taljaard et al., 2009a,b). In microtidal estuaries, as opposed to meso- and macrotidal estuaries, flushing of the water column (associated with water replenishment) and mixing forces (associated with oxygenation of the water column via wind and tidal currents) are limited. Inflowing river water typically creates stratified conditions whereby the less dense freshwater flows over denser saline bottom water. Due to the difference in density between these two water layers, mixing of the water column is significantly limited and bottom water hypoxia commonly occurs under such highly stratified conditions (Kurup and Hamilton, 2002; Snow and Taljaard, 2007; Du Laing, 2012). This has been recorded in certain southern Australian estuaries, particularly in south-west Victoria (Barton and Sherwood, 2004), and during partial mouth breaching events, when the oxygenated surface water flows over the saline water, leaving behind the hypoxic bottom water (Becker et al., 2009).

South African temporarily open/closed estuaries (TOCEs) share similar hydrological and morphological characteristics to many south-west Victorian estuaries (intermittently closed/open lakes and lagoons (ICOLLS)). Of the approximately 250 functional estuaries in South Africa (all are microtidal), 71% are classified as TOCEs. These systems are characterised by the presence of a berm (sandbar) at the mouth of the estuary, which separates it from the ocean for varying periods of time (Whitfield, 1992). In combination with marine sediment movement, the mouth of the estuary generally closes in response to periods of low river inflow whereas high river discharge causes the mouth to open. The conceptual model for water quality of South African TOCEs (Snow and Taljaard, 2007) proposes that during the open mouth state, physico-chemical gradients reflect a combination of that of the river (fresh) and seawater inflow. Nutrient concentrations are normally high

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