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# Towards the classification of eutrophic condition in estuaries

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ABSTRACT

Water quality and ecological integrity of estuaries closely reflect activities within the entire upstream catchment. Much emphasis has been placed on the response of estuaries to anthropogenic stressors through the use of monitoring programmes. Key to the success of these programmes is the use of indicators, as they transform data into useful information. The aim of this study was to identify the eutrophic condition of selected estuaries along the southern coast of South Africa, using a multi-metric approach to classification. Four permanently open and five temporarily open/closed estuaries were studied. Initially, the daily nutrient loads and flushing time variability were assessed for each estuary. Next, the "state" of the estuaries was determined using a variety of indicators, including: dissolved oxygen, inorganic nutrients (N and P), phytoplankton, epiphytes and microphytobenthos. Specific indicator thresholds, obtained from existing assessment frameworks and literature, enabled an incremental rating of eutrophic condition. Using this approach, an equal number of estuaries were classified as oligotrophic ('Good'), mesotrophic ('Fair') and eutrophic ('Poor'). High daily nutrient loads and/or long flushing times were identified as the primary causes of eutrophic conditions. However, differentiating between naturally and anthropogenically induced symptoms was highlighted as an important consideration in such assessments. This study demonstrated the importance of adopting a holistic and adaptive approach to the assessment of eutrophication in estuaries.



## 1. Introduction

The eutrophication of estuaries is largely a consequence of human-induced nutrient enrichment, and is recognised as a globally pertinent environmental issue due to inherent ecological and economic value associated with these ecosystems (Bricker et al., 2008; Zaldivar et al., 2008; Conley et al., 2009; Garmendia et al., 2012; McLaughlin et al., 2014). Eutrophication is defined by Nixon (1995) as *"an increase in the rate of supply of organic matter to an ecosystem"*. This definition is important in that it recognises eutrophication as a process rather than a state; however, from a management perspective it leaves considerable room for interpretation (Ferreira et al., 2011). Consequently, eutrophication has been scientifically and legally defined as "the enrichment of water by nutrients causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned" (OSPAR, 2003).

This definition is important in that it addresses the necessity for deleterious consequences (i.e. appreciable degradation of ecosystem health and/or sustainability) to occur, as a direct result of anthropogenic enrichment by nutrients, in order to be considered eutrophication (Tett et al., 2007; Ferreira et al., 2011). The natural progression of eutrophication symptoms generally entails an initial surge in phytoplankton biomass and/or macroalgal blooms, generally followed by more severe impacts such as a loss of submerged macrophytes, depleted oxygen levels, proliferations of harmful and toxic algal blooms, fish-kills, and the formation of "dead zones" (Bricker et al., 2003, 2008; Conley et al., 2009; Ferreira et al., 2011). As a result, legislation and mandates have been designed and implemented globally, with the primary objective of monitoring and protecting coastal ecosystems from anthropogenic degradation. Examples of such legislative instruments in the United States include the Clean Water Act (1972) and the Harmful Algal Bloom and Hypoxia Research and Control Act (1998). In Europe, the assessment of

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eutrophication in coastal waters is addressed by the Water Framework Directive (WFD; 2000/60/EC), the Nitrates Directive (ND; 1991/676/EC), the Urban Wastewater Treatment Directive (UWWTD; 1991/271/EC), and the Marine Strategy Framework Directive (MSFD; 2008/56/EC). Additionally, a variety of methods have been developed specifically to assess eutrophication and fulfil the requirements set out by the legislation. Some of these methods include the: Assessment of Estuarine Trophic Status (ASSETS), Water Framework Directive (WFD), Trophic State Index (TRIX), Environmental Protection Agency's National Coastal Assessment (EPA NCA), Transitional Water Quality Index (TWQI), OSPAR Comprehensive Procedure, and HELCOM Eutrophication Assessment Tool (HEAT) (Bricker et al., 2003; Ferreira et al., 2011; Borja et al., 2012). In South Africa, the National Water Act (No. 36 of 1998) makes provision for the protection of water resources, through the application of the Resource Directed Measures (RDM) method (Adams, 2014).

Eutrophication assessment methods form the basis of monitoring programmes aimed at assessing condition and detecting eutrophic trends, and subsequently provide the information required to establish ecological objectives (i.e. chemical and biological) (Ferreira et al., 2011; Garmendia et al., 2012; McLaughlin et al., 2014). This in turn enables the protection of pristine habitats, the identification of impaired water bodies, and the provision of goals for restoration or mitigation of systems already exhibiting the effects of eutrophication (McLaughlin et al., 2014). Furthermore, in line with the pressure-state-response framework, most assessment methods combine indicators of pressure (e.g. nutrient loads) with response indicators (e.g. primary producers) in order to evaluate the condition (or "state") of estuaries.

The aim of this study was to assess the eutrophic condition of selected estuaries along the southern coast of South Africa, in the Gouritz Water Management Area (WMA). The classification method used in this study is focused primarily on the two aspects fundamental to the definition of eutrophication, i.e. nutrients and primary producer response. The approach taken was similar to that prescribed by the ASSETS framework (i.e. multi-metric); however, variations exist due to the lack of a temporal aspect (i.e. 'once-off' sampling protocol) and the inclusion of additional indicator parameters. Furthermore, the main objective was to propose a method with which to classify the eutrophic condition of South African estuaries; whilst identifying the limitations and potential of the applied method for effectively assessing the state of eutrophication in these systems.

## 2. Materials and methods

### 2.1. Study area

The estuaries within the Gouritz WMA drain a total catchment area of approximately 53,139 km$^2$ (DEADP, 2011), before entering the Indian Ocean along the southern coast of South Africa (Fig. 1).

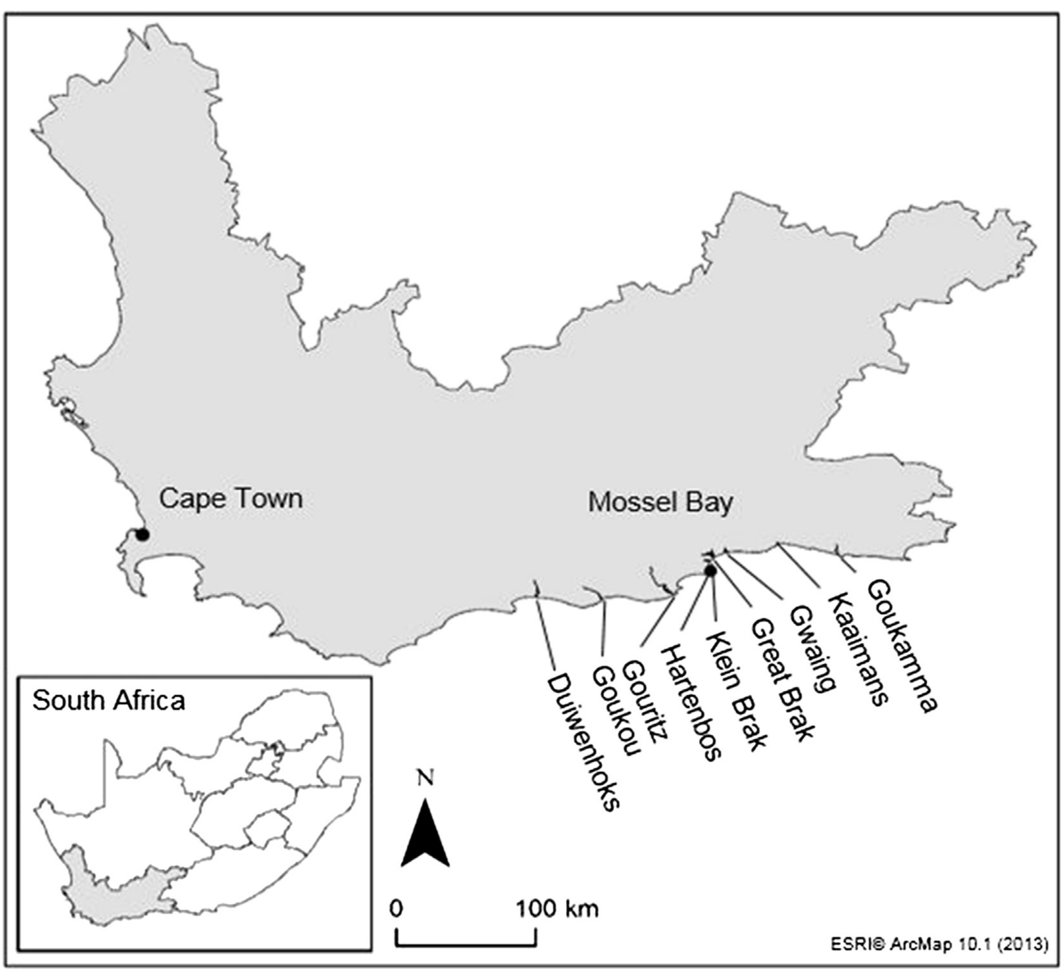


**Fig. 1.** Geographic distribution of the selected estuaries along the southern coast of South Africa.