Frequent artificial mouth breaching degrades Temporarily Open Closed Estuaries: Lessons learned and future concerns

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Background

Competition over water resources because of conflicting anthropogenic and environmental needs is a global challenge. Typically, this struggle translates into large-scale water storage or logistic measures such as impoundments and abstractions. Most coastal rivers are selected to provide for domestic, industrial and agricultural purposes, whilst not providing sufficient flow to sustain ecological processes. Indeed, the order of use prioritisation is not equitably or logically settled. In some cases, particularly in urban areas, abstraction is not the overarching issue. The use of critical estuarine environments has been extended to offerings of conduits or repositories of urban waste, actually increasing freshwater inflow to unnatural regimes. In urban areas in the context of north east South Africa, these occur either as a result of sustained freshwater inflows from waste water treatment works (WWTWs) or surges in runoff due to episodic events discharged to water courses and estuaries via storm water reticulation. The impact of this altered flow is evident on many systems regardless of their size, however these impacts appear magnified in temporarily open/closed estuaries (TOCEs) due to their small catchments (<100 km²) and characteristically low flow rates. This has significant implications for estuarine mouth state, a key factor governing the health of an estuary. Increased freshwater inflow, whether sustained or episodic, results in an increase in the frequency of mouth breaching. Post breaching, short term negative effects are evident in the estuary, particularly to the macrozoobenthos which are adversely impacted by sediment scour and prolonged exposure of the benthos. These impacts have a significant detrimental effect on the functioning of the TOCEs, which despite their low connectivity with the marine environment, are highly productive undertaking an integral nursery function for many higher taxa including commercially important fish and invertebrates. The focus of this study was to look at the estuary functional impacts of increased mouth breaching and the long-term manifestations of this; particularly should there be insufficient time between breaching events.

Methods

The uMhlanga Estuary is a perched TOCE situated ~20 km north of Durban on the east coast of South Africa. A small system, with a catchment of only 80 km² and natural mean annual runoff of ~0.4 m³.s⁻¹ (12.6 M m³.yr⁻¹), it is relatively well protected from a land cover perspective with little to no change surrounding the estuary. Conversely, instream effects are high with the uMhlanga catchment receiving a large volume of treated sewage from two waste water treatment works, the Mhlanga and Phoenix (5.9 ML.d⁻¹ and 27.6 ML.d⁻¹ respectively). This volume is anticipated to increase as urban growth occurs, with Mhlanga WWTW potentially going offline in the future, but Phoenix WWTW increasing to 50 ML.d⁻¹ to cater for the increased demand. This increase in treated sewage has resulted in an increased breach frequency, with breaching typically occurring twice monthly. To assess the affect that this change has had on the ecology of the system a collation of the historical data sets 1998, 2002, 2003 and 2009 as well as a current 2019 study provided us with a unique opportunity to assess the long term impact of increased and sustained flow on an estuary and its implications.
for estuarine function. All macrozoobenthic samples were collected from the same sites within the estuary (upper, middle and lower), at the same time of the year. Samples collected were identified to the lowest taxonomic level, enumerated and weighed. Corresponding physico-chemical samples were collected to characterise the physical environment. Data was root transformed and nMDS-ordinated by means of a Bray-Curtis similarity index with group average linking using the predictors ‘year’ and ‘station’ before spatial and temporal analysis. Taxa responsible for the observed grouping where shown through the similarity-percentage-breakdown routine.

Results
A clear change in the macrozoobenthic community occurred post 1998. This included a significant decline in richness and abundance and a change in the dominant species present. Overall, post 1998 macrozoobenthic abundance was an order of magnitude lower between (1998: 17 640 ± 7814 and 2002: 732 ± 975 respectively), with species richness declining to 4 ± 3 in 2002 compared to 14 ± 1 in 1998. This overall decline in richness and biomass did not improve through the subsequent periods. Not only was there an overall decline in richness and abundance but there was also a significant change in the species composition post 1998. The macrozoobenthic community in 1998 was characterised by species including *Prionospio multipinnulata*, *Desdemona ornata* and *Grandidierella lutosa*. Subsequent years were characterised by fewer hardier, opportunistic species including *Ceratonereis keiskamma* and *Capitellidae sp.* This change can be attributed directly to the increase in discharge from the WWTWs. Discharge from the Mhlanga WWTW commenced in 1975 with the Phoenix WWTW being operational from 1985. Combined discharge volumes however remained low (<5 ML.day⁻¹). These volumes have steadily increased to the high flow rates we see today (>30 ML.day⁻¹). The effect of increased discharge from the WWTW was not immediately evident, making it likely that there is a level of buffering with regards to flow rates existing within the estuary. By 1998 sewage volumes had already reached ~19 ML.day⁻¹, however it was only once a tipping point was reached and a significant increase in mouth breaching occurred that a rapid decline in the ecological state of the system occurred.

Conclusion
The overall decline in the ecological state of the estuary as a result of the WWTW provides great concern for TOCEs into the future. In South Africa TOCEs comprise 71% of the 290 estuaries present, dominating numerically and in spatial coverage, primarily occurring on the east coast of KwaZulu-Natal (KZN). Many of these systems occur in rapidly urbanising areas making them vulnerable to change. This rapid urbanisation is also evident throughout the western Indian Ocean region, and cognisance of the lessons learned in the Mhlanga Estuary and the potential impact of rapid urbanised growth can have on these systems is needed, particularly where more coastal friendly options, such as marine outfalls are not an infrastructure option. In addition, this study can potentially provide insight into how these small systems will react to climate change. Future climate models for KZN predict increased and sustained rainfall of 0.1 and 0.3 mm.day⁻¹ dependent on season, likely to result in increased freshwater flow into TOCEs, with increased breaching frequency. Here, increased breaching frequency has a negative impact on the macrozoobenthos and therefore the greater estuary-associated food web. These findings highlight the sensitivity that these TOCEs have with regards to anthropogenic and anticipated climate-related altered freshwater flow and the subsequent negative impact it can have on the ecology of the system.