ESTUARIES

St Lucia at an ecological tipping point?

St Lucia is progressing along a geological trajectory that has taken it from its ancestral form of a large deep estuary with major connections to the sea, to the shallow estuarine lake system it is at present, and onwards to a future state as a coastal floodplain containing freshwater pans and extensive swampland. Indications are that St Lucia is close to an ecological tipping point where it is about to change into the latter of these states, after which it will no longer function as an estuarine lake system. So writes Ricky Taylor and Alan Whitfield.

Turbid, sediment-rich uMfolozi River water in the Narrows, the indirect cause of the transformation of the St Lucia estuarine lake system into a freshwater lake system.

When this will occur, we do not know – it depends on estuarine channel connectivity, episodic river floods, sea-level rise, and the rate at which sediments accumulate in the existing St Lucia Estuary, Narrows, South Lake, North Lake and False Bay. But there are already strong indications that the system is on the cusp of switching from an estuarine lake system to a predominantly freshwater coastal lake and swamp system, with only a very small estuary component – comprising the existing Narrows, St Lucia Estuary and a small portion of the lower uMfolozi River that receives some saline inputs when the joint mouth is open to the sea.

This article describes how this once thriving estuary, which should act as a crucial nursery for marine fish stocks along a large proportion of the South African coastline, is rapidly losing its estuarine functionality. The details outlining this loss have been described in a variety of scientific papers over the past two decades, some of which are summarised in a recent review article in the ***African Journal of Aquatic Science*** by Taylor, Whitfield, Fox and Adams. Indeed, the St Lucia system has, until recently, provided approximately 50% of the estuarine surface area for all South African estuaries combined. Loss of the lake as an estuarine system, in particular, would have a major impact

on fish and swimming prawn stocks of the subcontinent, upon which subsistence and small-scale artisanal fisheries depend, as well as the KwaZulu-Natal penaeid prawn commercial fishery that was once very active on the offshore Thukela Banks to the south of St Lucia.

North-eastward aerial view of Lake St Lucia, from Makakatana Bay looking across South Lake towards the coastal vegetated dune system in the far distance.

The St Lucia estuarine system is recognised for its beauty, its changeability and its biodiversity. It is a core feature of the iSimangaliso Wetland Park World Heritage Site and is a Ramsar Site of International Importance. It is well named iSimangaliso, meaning "place of wonder". It is Africa's largest estuarine lake that supports large populations of hippos, crocodiles and colonial-breeding birds such as pelicans, cormorants, terns, herons, gulls, pratincoles and other species. It is a magnet for regional and local tourism, being an important economic contributor to the local people, as well as attracting international tourists to South Africa.

The original St Lucia Game Reserve was established in 1896 to conserve one of the last major refuges for hippopotamus herds in South Africa at that time.

A feature of St Lucia is its continually changing salinity in response to natural wet-dry rainfall cycles. The estuarine lake has a surface area of approximately 35 000 ha, depending on water level, yet it has an average depth of less than one metre. The large surface area to volume ratio means that it is very sensitive to evaporation losses, which concentrate the salt in the water, or to the addition of rainfall or river runoff, which dilutes the saltiness. The result is that St Lucia is at times in a low-salinity state where it is dominated by both estuarine and freshwater plant and animal species. However, most of the time, it is in a range of salinities where it is dominated by estuary-associated marine and estuarine flora and fauna. At the other extreme, the estuary may reach salinity concentrations that are well above that of seawater, i.e., hypersaline. After a period of several successive dry years, much of the water may evaporate from this shallow system, exposing large areas of the lake bed. At each stage, as salinity changes, it supports those plants and animals that can cope with the ambient salinity of that stage.

To be a fully functional estuary, the ideal salinity should be in the 4 to 35 parts per thousand (ppt) range (seawater = 35 ppt), and there should also be a link with the sea through an open estuary mouth. It does not have to be open all the time, but for long enough periods to enable juvenile fish and invertebrates to enter from the sea, or leave the estuary as adults to breed in the marine environment. It is as a functioning estuary that St Lucia is of greatest benefit to the rich fauna and flora, as well as to people. It is to maintain this estuarine condition that all past management interventions have been directed. These actions have mostly focused on countering the effects of human-induced changes, including altered river flow regimes that increased salinity and promoted extended mouth closures, as well as increased quantities of sediment coming from the catchment areas that have promoted shallowing and constrictions developing within the system.

Extensive sedimentation in the St Lucia Estuary is clearly visible in this low tide aerial photo taken in 2023. These mainly compacted mud sediments effectively prevent the prevalence of a large tidal prism within the shallow estuary, and this therefore works against the retention and transport of saline water up the system.

To understand St Lucia, it is necessary to know about its geological evolution. At the peak of the most recent Glacial Period (~18000 years ago), the sea was about 120 m below the present-day level. As the earth warmed there was a rise in sea level, causing the basin that is now St Lucia to become an estuarine lake, and creating the conditions where the coastal dunes could form and be colonised by subtropical dune vegetation. The 'ancestral' St Lucia was much larger than the current system, and much deeper. It was fed mainly by the uMfolozi, uMkhuze and a few smaller rivers. These carried sediments into the St Lucia basin, and sand from the sea also entered the system. Slowly, the St Lucia basin filled, until it became the shallow estuarine lake that we know today. Some

parts of the ancestral lake have filled in completely. These are now the uMkhuze and uMfolozi floodplains that are colonised by swampland vegetation.

The processes driving geological change have not stopped. St Lucia continues to accumulate sediment, and the trajectory is for St Lucia to fill up completely. In time, the system will resemble the current uMfolozi and uMkhuze floodplains. Both of these have considerable conservation value as freshwater wetlands with some shallow open water areas that assist in trapping sediments brought down by river flooding. Ultimately, St Lucia will no longer function as an estuary. The unfortunate thing is that the rate of the trajectory towards this state has been considerably accelerated by human activities, particularly accelerated soil erosion in the river catchments. Most of the St Lucia management interventions up until now have tried to slow down this artificially rapid change. In the 1950s the link between the uMfolozi River and St Lucia Estuary was closed to keep high sediment loads out of the estuary, in the 1960s dredging and hard structures were built in the estuary mouth to prevent sediments from blocking the estuary-sea link, and in the late 1970s a canal (the uMfolozi-St Lucia Link Canal) was constructed to bring in additional freshwater to St Lucia at times when the sediment load in the river was low. In January 1984, Cyclone Domoina washed away the hard structures at the mouth, destroyed the near-complete uMfolozi intake works, and severely damaged the link canal, never to be repaired.

A river bank breach into the Link Canal brings large amounts of sediment-rich uMfolozi River water into the Honeymoon Bend area of the St Lucia Estuary during river flooding. This breach needs to be blocked as a matter of extreme urgency if Lake St Lucia is to retain its connection with the sea.

The management dilemma has always been to either accept the sediment that comes with the uMfolozi water, or not have its water with the risk of the lake becoming extremely hypersaline and possibly even drying out altogether if the mouth remains closed during the time of a prolonged drought. Simplistically put, the management objective has been to keep St Lucia as a functional estuary – but without the uMfolozi water there have been ever increasing periods of hypersalinity and reduced lake aquatic habitat due to a major water shortage caused by extensive evaporation from the lake surface. The alternative has been to shorten the geological lifespan of Lake St Lucia by adding uMfolozi River water to St Lucia, which contains large amounts of sediment linked to increasing catchment degradation – a stark choice indeed!

Is there a compromise? The most recent management intervention of reconnecting the uMfolozi River with St Lucia had its origins in May 2010 when the Water Research Commission (WRC) funded a symposium held at St Lucia that gathered scientists with expertise on both the St Lucia and uMfolozi systems to discuss this issue. The proceedings from this meeting were published as a WRC Report, ***A review of studies on the uMfolozi Estuary and associated flood plain, with emphasis on information required by management for future reconnection of the river to the St Lucia system*** (**WRC report no. KV255/10,** https://tinyurl.com/3czv57a5).

The dual estuary mouth system that was artificially maintained between the 1950s and 2012, showing both an uMfolozi Estuary mouth in the top of the photo and a St Lucia Estuary mouth in the middle of the photo.

Following on this, in 2011 the iSimangaliso Wetland Park Authority (ISWPA) altered the policy that mandated that the uMfolozi River should be kept separate from St Lucia. The Authority obtained funding from the World Bank's Global Environment Facility (GEF) to undertake studies to investigate how this could be achieved. These studies indicated that reconnection, in its original configuration, could result in a system that would function naturally and bring uMfolozi River water into St Lucia. The system would have a single estuary mouth that would breach without human intervention, i.e., when water levels overtopped the beach berm or when there was a large river flood. The concept was that the rush of water during such a river flood would increase water levels in the estuary and trigger breaching that would flush accumulated sediment from the system into the sea. GEF funding was then used to reconnect the uMfolozi with St Lucia, an intervention which was achieved in July 2012.

Unimpeded uMfolozi water has been entering the St Lucia system since 2012, but the joint estuary mouth has remained predominantly closed for a continuous period between the beginning of 2015 and end of 2020. During this time, large quantities of sediment were deposited in the St Lucia Estuary and Narrows, encouraging littoral vegetation growth as well as reducing channel width and depth. This has severely reduced

water flows within the estuary, Narrows and Potter's Channel. Part of the reason that the estuary mouth did not breach naturally during uMfolozi River flooding over this period was that Lake St Lucia had to fill up first before water levels at the Estuary could overtop the berm. Prolonged closure of the mouth meant that saline water was not entering Lake St Lucia, which was becoming increasingly 'fresh' and less 'estuarine' during this process.

Aerial view of St Lucia Estuary berm and muddy uMfolozi waters entering from the upper right of the photo. These conditions persisted for more than five years between 2015 and 2020.

Eventually, the lack of estuarine-marine connectivity, together with flooding of farmland on the uMfolozi floodplain, necessitated an 'assisted estuary mouth breach' following river flooding in January 2021. Unfortunately, much of the fine sediment that had accumulated in the estuary over the many years of mouth closure had compacted, forming an erosion resistant 'sill' within the estuary and mouth region in particular, and was not flushed out to sea. This compacted mud 'sill' also prevented the estuary mouth from migrating northwards in the normal manner once the estuary opened. The reduced tidal exchange of water meant that the suspension and scouring of sediments from the estuary and Narrows towards the sea did not take place as expected. This reduced the extent of the tidal prism, which then barely reached the St Lucia Bridge and meant that saline waters did not penetrate up the Narrows, let alone reach the lake. The result was that Lake St Lucia became increasingly more like a freshwater coastal lake system than an estuarine lake. Only the St Lucia Estuary seawards of the road bridge showed signs of being estuarine, and even here, the tidal exchange was muted due to the shallowness and restricted channel dimensions in the area. In June 2021, the St Lucia Estuary mouth closed naturally.

In April 2022 river-flooding caused the estuary mouth to breach – this time naturally. Again, the scouring of accumulated sediments from the estuary was limited and, once the floodwaters had dissipated, only a relatively small tidal prism was recorded. No seawater was documented reaching the St Lucia Bridge in the first two years that the mouth has remained open. The estuary mouth channel has remained relatively fixed due to compacted mud remaining in place, preventing the natural northward migration of this channel. This 'fixing' of the estuary mouth may well have prolonged the 2022-2025 open phase since 'wandering' estuary mouths are more prone to closure.

However, a major concern of aquatic ecologists is the lack of tidal prism and penetration of marine waters up the St Lucia system during the open mouth phase. This persistent feature during both recent open mouth states signals a transformation of St Lucia from an estuarine coastal lake system into a freshwater coastal lake system.

uMfolozi River floodwaters leaving the St Lucia Estuary via the Beach Channel (left) and Estuary Channel (right) after the natural mouth breach in April 2022.

Two other 'problems' have come into focus during the past decade. Firstly, the decommissioned Link Canal has been breached by floods in the uMfolozi River. The canal now carries large amounts of sediment directly into the estuary near Honeymoon Bend with each flood. This sediment deposit and the growth of reeds towards the middle of the channel from the banks have formed a constriction that inhibits the inward (upstream) movement of tidal water, and thus prevents saline water from moving any distance up the Narrows. The healthy state of freshwater shoreline reeds, which cannot survive saline water that is over 12 ppt, is a testament to the lack of saline intrusion up the Estuary and into the Narrows. An urgent action that needs to be initiated by the ISWPA is the physical blocking of the two points where the uMfolozi River has broken into the relic Link Canal. Following the creation of this blockage, accumulated sediments in the Honeymoon Bend area will need to be removed.

In a similar manner, management action is required at the junction between the Narrows and South Lake. Currently, the quantity of water pushed into the Narrows from the Lake by wind is limited considerably by extensive and dense vegetation growth in the Potter's Channel - Brodie's Shallows area (where the Narrows meets with the Lake). As the lake level rises due to river flow into False Bay and North Lake, the result is a head of water in the lake relative to the Narrows. Currently, this lake water can only 'seep' through the dense vegetation towards the Narrows when such conditions occur. Conversely, little or no movement of saline water can occur from the Narrows into the lake due to these extensive beds of submerged and emergent floodplain vegetation in the Brodie's Shallows area. The urgent restoration of Potter's Channel is therefore required if Lake St Lucia is to receive saline water up the Narrows and therefore remain estuarine.

Google Earth satellite image of the Narrows (upper centre of photo), St Lucia Estuary (centre of photo) and uMfolozi River Beach Channel (lower right of photo). The introduction of turbid, sediment rich uMfolozi River water to both the estuary and Narrows by the Link Canal (bottom and centre right of photo) is clearly visible in the Honeymoon Bend area (centre of photo). A turbid water plume is visible in the sea in the bottom right of the photo. Note the clear dark water entering the joint estuary mouth from the Beach Channel, indicating that the turbid uMfolozi River water is not entering the sea via the Beach Channel but rather via the Link Canal.

Aerial view across the Makakatana Bay southern shore towards Potter's Channel and Brodie's Shallows in the upper central portion of the photo.

Aquatic biotic movements between the estuary and lake are also affected. Although marine larval and juvenile fish and invertebrates are currently able to find a path through these extensive plant beds and into the lake, the return migration to the sea to breed by adults of these species may be severely compromised if the Potter's Channel is not restored. Support for this view is the absence of the adult flathead mullet annual spawning migration from False Bay and North Lake, into South Lake and then down the Narrows during April/May. In the last century, these mullet shoals were preyed upon by large gatherings of crocodiles and flocks of pelicans in the Narrows, an event that appears to have been lost in recent decades.

There are 'symptoms' indicating that St Lucia is very close to its geological tipping point, after which it will no longer function as an estuary.

Also of importance is the low salinity prevailing in the lake – for the past three years South Lake, North Lake and False Bay have recorded salinities below 6 ppt. If this level falls below 3 ppt for any length of time, massive fish kills of marine fish species will likely occur and juvenile recruitment of marine fish species

into the lake will cease. In the process, approximately 50% of the estuarine nursery area in South Africa for estuary-associated marine fish species will be lost.

Something that came out very clearly in our scientific review is that there are 'symptoms' indicating that St Lucia is very close to its geological tipping point, after which it will no longer function as an estuary. This is likely to be irreversible and, in the process, South Africa will have lost 35 000 ha of estuarine habitat. When this will happen depends on whether there are any mega-floods entering Lake St Lucia and/or coming down the uMfolozi River in the near future. As was the case with Cyclone Domoina, such ecological reset events are episodic and unpredictable. However, given the rapidity of climate change, it may be increasingly likely that northern KwaZulu-Natal may experience more cyclones as the cyclone belt moves southward. This increases the probability of St Lucia being 'hit' by such an event in the not-too-distant future.

What will St Lucia look like after it has passed the above-mentioned 'tipping point'? The lake will likely become an ephemeral shallow freshwater system during wet periods that dries up completely during extended dry periods. After the 'tipping point', there will no longer be a marine-estuary link with the lake, there will be no seawater exchange, and there will be further accumulation of sediments, which will reduce connectivity even further. It will therefore no longer be a functional estuarine lake system. During extended droughts, the now freshwater lake may dry completely to form a desiccated mud flat.

The St Lucia system is currently a "place of wonder". Some of that wonder will disappear if it is prematurely transformed into a freshwater coastal lake system.

So, how should St Lucia be managed going forward? In the near future, ISWPA management actions should be to initiate a few relatively small interventions that will help retain St Lucia its estuarine state for as long as possible. This is the state that is of greatest value to both the species richness of St Lucia and to humans. This is currently within our power to implement, but at some stage, there will be little more we can do. Then the decision will have to be made to 'let the system go', and allow it to pass through the tipping point to the next phase in its natural geological trajectory.

Three adaptive management actions are required in the short term to temporarily steer St Lucia back towards an estuarine trajectory. The most important action by far is the closure of the Mfolozi-St Lucia Link Canal, which was decommissioned after the huge 1984 Domoina cyclonic flooding. This canal is a conduit that carries uMfolozi flood sediments into the Honeymoon Bend area of St Lucia and causes a major constriction in the Estuary. To restore estuarine hydrological functioning, it may then be necessary, once the canal has been blocked off, to remove the accumulated sediment at the point where this canal enters the Honeymoon Bend area. This accumulated sediment currently prevents the inflow of marine tidal water into the upper estuary and Narrows.

Another important action is to open the Potter's Channel link between the southern part of the lake and the Narrows. The emergent and submerged vegetation there prevents free water movement between the Lake and Narrows, and vice versa. Unless this constriction to flow is opened up by recreating Potter's Channel, Lake St Lucia will become a freshwater lake. To promote the lifecycles of estuary dependent fish and invertebrate species between the estuary and sea, the combined St Lucia-Mfolozi Estuary mouth will need to be artificially breached if the mouth remains closed for prolonged periods that exceed three years.

When will it be necessary to allow St Lucia to progress to the state of a freshwater and floodplain wetland? This we do not know as the rate of geological change can be slowed by mega-floods and sea-level change, or speeded up by accelerated sediment yields from the catchment. Monitoring is needed to track the change and to guide the managers when to make the decision that further management actions are futile. From this point onwards there will be novel ecological conditions in St Lucia – that will still have significant conservation value for the system. We do need to embrace change and adapt to new opportunities, as well as guide conservation along these new scenarios.

A comprehensive hydro-ecological monitoring programme needs to be established in the St Lucia system, something that has been largely absent over the past decade. Although monitoring is key to guiding management, little of what will occur in the future can be backed by hard data at present. This must be done by science-based considered opinions, based on expertise, ecological and geological scientific theory and principles. In this regard, there is a considerable amount of existing scientific knowledge relating to St Lucia. The management authorities must involve experienced scientists who have worked at St Lucia for many decades to provide this advice. Conservation will be going into new territory as St Lucia changes – and this should lead us into new thinking to accompany these changes.