ST LUCIA
2001 to 2012: A decade of drought

Management interventions and what we have learnt about the ecosystem

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St Lucia 2001 to 2012: A Decade of Drought

Management interventions and what we have learnt about the ecosystem

Report to the

Water Research Commission

by

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EXECUTIVE SUMMARY

BACKGROUND AND RATIONALE

In 2001 rainfall in the catchments of Lake St Lucia was above average, the rivers entering the lake were flowing strongly, the St Lucia mouth was open and salinity in the system was low. Water levels were high, boating was easy and angling was good. Two years prior to this the area had been awarded World Heritage Site status in recognition of its global status as a superlative natural area. Then the situation changed. Below average rainfall was recorded most years for the period 2001 to 2012, and there was little flow in the rivers. The St Lucia mouth closed and the authorities decided against dredging it open. This was a controversial management decision. The cumulative freshwater deficit manifested as lowered water levels and hypersalinity.

At the onset of the drought the accepted management philosophy of breaching the mouth to maintain connectivity between the lake and the sea was overturned and the mouth was allowed to stay closed. However it was soon after the start of the drought, during the DWA Water Reserve Determination exercise, that the full implications of having the Mfolozi River separated from St Lucia were realised. But it was still strongly embedded in the management philosophy that, if the Mfolozi River was reconnected to St Lucia, the quantity of sediments that would enter St Lucia would be of long-term detriment to the system and it would be preferable to allow the system to be affected by short-term lowering of water levels.

This document is a record of the impacts of the 2001 to 2012 drought at St Lucia. It provides a record of the impacts of the drought on the estuarine system, and details on the management interventions that were conducted.

During the drought there were a number of physical changes. Large portions of the St Lucia lake bed dried. As the lake dried up salt concentrated in the remaining water reaching record heights of salinity. It then dried up completely leaving a crust of precipitated salt on the cracked mud. Wind shifted sediments within and out of the lake basin. Shoreline margins changed shape and hummocks of grass trapped mounds of sediment.

There have been many interesting biological responses over this past decade. These have included die-offs of estuarine fish and little opportunity for them to recruit from the sea. In response, with the lack of competition, the Tilapia populations increased exponentially. So much so that thousands of Great White Pelicans were consuming an estimated 15 tonnes of these fish each day during peak periods. Groundwater seepage along at least 40 km of St Lucia's 400 km of shoreline supported a rich groundwater-dependent vegetation, and in other areas there have been large 'fields' of succulent salt-marsh, new areas of reed beds line the Narrows and the mangroves are still healthy. In the northern part of the lake, where salinity was at its highest, the food chain was reduced to a simple form with only few species and characterised by a bloom of orange-coloured cyanobacteria.

In the past decade the management authorities implemented several management actions. Initially the effort was focussed on the maintenance of the sediment trap inland of the mouth and the preparation to breach the mouth when the time was right. Then effort went into separating and keeping the Mfolozi Mouth separate from St Lucia – in line with the management objective of not allowing the Mfolozi into St Lucia for fear of increased sediment accumulation. More recently, since 2008, the managers experimented with small-scale linkages of the Mfolozi River via the Back Channel – a disused channel excavated in about 1970. This has proved to be a highly successful management intervention, albeit only at a small-scale. It has allowed backed-up, sediment-free freshwater from the Mfolozi to enter St Lucia whenever the Mfolozi Estuary mouth closed, but this backing-up caused some of the low-lying sugar farms to be flooded. In addition, whenever the Mfolozi Mouth has been open, sea water has entered St Lucia via this Back Channel at high spring tides, allowing some recruitment of marine organisms. This has been a unidirectional movement – from the sea into St Lucia, but not in the other direction.

In 2010, to synthesize the knowledge necessary to implement a re-linkage of the Mfolozi to St Lucia, the Water Research Commission supported a very successful 'Indaba' to allow all the involved scientists to present their knowledge. The proceedings of this have been published as the Water Research Commission Report KV 255/10. The issue of sediment inputs is still largely an unknown. Indications are that the quantities of sediment brought down by the Mfolozi River are less than we had thought – and that a lot of the sediment was in fact of marine origin. It was in 2011 that the decision was taken to re-connect the Mfolozi to St Lucia via a newly excavated Beach Channel.

Other events have also impacted on the system during this drought period. Two important ones were associated with cyclones.

In March 2007 extreme high seas, caused by the coincidence of very high tides, storm surges and the influence of Cyclone Gamede, breached the St Lucia Mouth. This stayed open for six months before closing naturally. In this time a large quantity of seawater flowed into St Lucia, raising water levels and introducing salt. What was the long-term influence of this, and was the mouth breach affected by the dredging that had been conducted some time prior to the breaching event? This was a natural 'management experiment' which still needs to be described and from which there is the opportunity to learn and if necessary to adapt future management strategies.

In March 2012 Cyclone Irina brought a lot of rain to St Lucia, but not to the inland catchment areas. This was not adequate to open the mouth. However from early September 2012, heavy and consistent rains caused the rivers to flow and break the drought. The summer of 2012-2013 turned out to be particularly wet, with well above average rains falling in the catchment area. All the rivers entering St Lucia carried water most of this summer period and the Mfolozi River overtopped into the abandoned Link Canal bringing huge quantities of freshwater into St Lucia. The water level in St Lucia increased by more than a metre in the summer period and salinity levels dropped.

St Lucia still has a shortage of freshwater and controversy about management continues. A Global Environment Facility (GEF) funded project is currently underway to assess the situation and to make recommendations of various long-term options to relieve the situation. It will then set course to rectify the problems relating to the long-term management of St Lucia.

AIMS AND METHODS

The aim of this report has been to document the course of the 2001 to 2012 drought, describe how the hydrological and biotic components of the St Lucia ecosystem responded and discuss the management interventions that occurred.

This project has had three components:

To accumulate materials and available literature that describes the drought. These are described in Appendix 1.

To create a 'timeline' of events and management interventions. This is Appendix 2.

To describe the ecological responses to the drought and the management interventions (Main Report).

The purpose has not been to repeat information that is already captured in formal sources – such as in published scientific literature – but to capture the informal knowledge and experience gained during the 2001 to 2012 drought period.

RESULTS AND DISCUSSION

The document produced is a record that will inform future managers and researchers of the 2001 to 2012 drought and how it affected St Lucia.

The interpretation of events and the management of St Lucia are based on personal value judgments formed through experience and exposure to specific places and events. Nobody can predict the duration or magnitude of a drought. It therefore must be realised that all decisions were taken with the best of intentions at a time when nobody could know that the drought could last for over a decade.

RECOMMENDATIONS FOR FUTURE RESEARCH

The St Lucia estuarine system has catchments that are transformed by human activities. With time the degree of transformation will increase and this will impact St Lucia. The changes will be related to freshwater supply and to accelerated sedimentation. New threats are those of altered water quality and the impacts of alien invasive species. Future research should focus on all of these topics.

The scale of management should change to consider the full catchment and have a long-term view of future changes. Future research should be directed at ways to reduce catchment-level impacts. Management should not just be 'activated' during drought periods – but have a full wet-dry cycle level of consideration.

At the time of writing, the WRC has commissioned a workshop and document to consider the future direction that research in the Natural Sciences relating to St Lucia should be taking.

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CRUZ	Coastal Research Unit, Zululand
CWAC	Coordinated Waterbird Counts
DWA	Department of Water Affairs
EKZNW	Ezemvelo KZN Wildlife
iSimangaliso	iSimangaliso Wetland Park
iSimangaliso Authority	iSimangaliso Wetland Park Authority
MSL	Mean Sea Level
NMMU	Nelson Mandela Metropolitan University
NPB	Natal Parks Board – precursor to Ezemvelo
NUFU	Norwegian University Fund
UCOSP	Umfolozi Cooperative Sugar Planters
UKZN	University of KwaZulu-Natal
UniZul	University of Zululand

LIST OF APPENDICES

1 INTRODUCTION AND OBJECTIVES

1.1 Background

In 2001 rainfall in the catchments of Lake St Lucia was above average, the rivers entering the lake were flowing strongly, the St Lucia mouth was open and salinity in the system was low. Water levels were high, boating was easy and angling was good. Two years prior to this the area had been awarded World Heritage Site status. Then the situation changed. Below average rainfall was recorded for most years from then until September 2012 and there was little or no flow in the rivers. The St Lucia Mouth closed and the authorities decided against dredging it open. This was a controversial management decision. The cumulative freshwater deficit manifested as low water levels and hypersaline conditions.

At the onset of the drought the accepted management philosophy of breaching the mouth to maintain connectivity between the lake and the sea was overturned and the mouth was allowed to stay closed. However it was soon after the start of the drought, during the DWA Water Reserve Determination exercise, that the full implications of having the Mfolozi River separated from St Lucia were realised. But it was still strongly embedded in the management philosophy that the quantity of sediments that would enter the system would be of long-term detriment to the system and it would be preferable to allow the system to be affected by short-term lowering of water levels. Nobody could have predicted the duration or magnitude of the drought – so all decisions were taken without knowing that the drought was to extend for over a decade.

In 2010, to accumulate the knowledge necessary to implement a re-linkage of the Mfolozi to St Lucia, the Water Research Commission supported a successful 'Indaba' to allow all the involved scientists to present their knowledge. The proceedings of this have been published as the Water Research Commission Report KV 255/10 entitled "**A review of studies on the Mfolozi Estuary and associated flood plain, with emphasis on information required by management for future reconnection of the river to the St Lucia system**" (Bate et al 2011). This was a landmark document as, prior to it, little was known or had been written about this area. This document was to provide the information needed to change management directions.

However, a key issue, that of sediment inputs, is still unresolved. Indications are that the quantities of sediment brought down by the Mfolozi River are less than we had thought – and that a lot of the sediment that accumulates in the mouth area has its origins in the marine environment. This change in thinking has led to a different management approach which is now focused on linking the Mfolozi Estuary to St Lucia rather than keeping the two estuaries separate.

In the past few years the management agencies have been experimenting with small-scale linkages of the Mfolozi River to the St Lucia Narrows via the Back Channel – a disused channel excavated in about 1970. This proved to be a successful management intervention, albeit only at a small-scale. It allowed backed-up freshwater from the Mfolozi to enter St Lucia whenever the Mfolozi Estuary Mouth closed; but this backing-up hindered drainage of the lower sugarcane farms and caused some of them to be flooded. In addition, whenever the Mfolozi Mouth has been open, the Back Channel has allowed sea water at high spring tides to enter St Lucia via this Back Channel, allowing some movement of marine organisms – from the sea into St Lucia. It does not allow biotic movement in the other direction.

In March 2007 extreme high seas, caused by the coincidence of very high tides, storm surges and the influence of Cyclone Gamede, breached the St Lucia Mouth. This stayed open for six months before closing naturally. In this time seawater flowed into St Lucia, raising water levels and introducing a large quantity of salt. In March 2012 Cyclone Irina brought a lot of rain to St Lucia, but not to its inland catchment areas. This was not adequate to open the mouth. Starting in early September 2012 heavy and consistent rains caused the rivers to flow for the whole of the 2012-13 summer period. The drought that had persisted for over a decade was broken.

There have been many interesting biological responses over this past decade. These have included die-offs of estuarine fish and little opportunity for them to recruit from the sea. In response, with the lack of competition, the Tilapia populations increased exponentially. So much so that in 2005 thousands of Great White Pelicans were consuming well in excess of 10 tonnes of these fish each day during peak periods. Groundwater seepage along at least 40 km of St Lucia's 400 km of shoreline has supported a rich groundwater-dependent vegetation, and in other areas there have been large 'fields' of succulent salt-marsh, new areas of reed beds and the mangroves are surviving. In the northern part of the lake the food chain was reduced to a simple form with few species, characterised by a bloom of orange-coloured cyanobacteria.

There also have been physical changes. Large portions of the lake bed dried and the dust picked up by the wind shifted sediments within and out of the lake basin. Shoreline margins changed and hummocks of grass trapped mounds of sediment.

Overall, St Lucia has had a shortage of freshwater for a decade and the controversy around management continues. The purpose of this report is to document the ecological changes that occurred during this drought period and learn from the management interventions. Prior to this there have been two prolonged and severe droughts in the past 70 years – that of the late 1940s to 1950s and that of the early 1970s. The management interventions for both differed and were different from the current drought – and some of the consequences of these management actions are still evident at St Lucia. However, there is little documented as to why the various decisions were taken or what the responses of the system were.

Some of the above has been described in a series of scientific studies conducted over the past decade, but much of this is incidental knowledge as little of the research conducted was initiated with the aim of documenting the progression of the drought and its effects.

2 MANAGEMENT PHILOSOPHY AND GUIDELINES

This document reviews the progression of the 2002-2012 drought at St Lucia and the management interventions taken to conserve the estuarine system. It considers the natural system and describes its responses during the progression of the drought (Section 3). It considers the management actions taken to counter the adverse impacts of the drought (Section 4). This section considers the background philosophy of conservation and the objectives for the conservation management of the estuarine system.

2.1 Guidelines for the management of natural systems

The current philosophy for the management of natural areas is to manage a full ecosystem if possible, and not parts of it in isolation. This has not always been the approach at St Lucia. Conservation has gone through phases of:

Maintain and enhance the area for the benefit of the users. For example one of the reasons for setting aside the St Lucia area in 1895 was to look after the game populations for hunting which was a significant part of the economy of Natal in the late 1800s. At this time little recognition was given to the fact that this was part of a larger ecosystem.

Within the conserved area in the first half of the 20th century focus was given to the management of certain species – usually specific types of antelopes or fish stocks.

At this same time there was little understanding that a natural area is dynamic, that there are a number of processes operating all the time and that change is a natural part of a system.

Conservation often set out to maintain the status quo. This was the case at St Lucia at the start of the drought of the 1940s to 1950s

When management was required, it often went through the 'control and dominate' approach; where the management interventions were carried out with heavy interventions. Engineering solutions were mostly used to dominate nature and natural processes, as was the case in the 1960s to 1984 in St Lucia.

At St Lucia the conservation managers have applied all the above types of management in the past century. However since the 1984 'Domoina flood' there was a move to have a lighter touch with less intervention.

Currently, the basic tenets guiding nature conservation are:
To allow the system to function as naturally as possible with little human intervention. But it is rarely possible to achieve this as few systems are intact. Seldom can we conserve a full and intact ecosystem.
To maintain the dynamic nature of the system. The approach is to maintain the natural processes and only where these have been damaged to intervene with management action. The management action should be to restore lost or damaged processes, to mimic with the intervention the natural processes or to intervene to substitute for a process that has been lost and cannot be restored.
To design management interventions in harmony with the natural processes – i.e. to work with the processes not against them.
To base management interventions on knowledge. To underpin interventions with scientific understanding, to develop conceptual models of how the system functions and to quantify these models where possible.
To use these models to test alternative management scenarios before implementation.
To learn and change; to apply adaptive management. This requires specification of objectives of the management, good documentation of the interventions and to review what has been done to see if the intervention has achieved its objective. It is a process of using the management intervention in an experimental manner and then learning by doing.
The use, or actions taken, must be sustainable (this includes tourism, developments and extractive uses, such as fishing.)
Wherever possible a precautionary approach should be taken, being mindful of the fact that there are often unforeseen responses to management interventions.

2.2 Conceptual understanding and the communication of management objectives

All management actions are taken with the purpose of achieving a result. As conservation areas are managed by teams, it is important that the end point of a management action is well defined. In other words, "What is the end product that is wanted?" and "What is the purpose of doing the management?" These questions must be asked in the context of the current overall management aim for the area or component of the area. These have been expressed in the form of management plans or guideline documents. Management guidelines for the estuarine system have not been clear and well communicated – mainly because our understanding of the dynamics for the management of the system is often fuzzy and incomplete. Objectives for management are evolving continuously as knowledge improves. However, as St Lucia is affected by wet-dry cycles, managers change and knowledge of what happened and what was done in the previous wet-dry cycle is not remembered or recorded. Too often the ‘wheel is reinvented’. One of the purposes of this document is to record what knowledge has been gained during this drought and what we have learnt from the management interventions implemented.

3 DESCRIPTION AND ASSESSMENT OF MANAGEMENT ACTIONS

3.1 Context and management objectives

The management that was carried out in the 2002-2012 period was done in the context of what was believed to be the correct course of action at the time. As the drought progressed, so some changes occurred in mindsets, and this altered the management objectives to new approaches that are currently believed to be the correct course of management. At the start of the drought the prevailing thought was that the St Lucia Mouth should not stay closed for more than 18 months, that the Mfolozi Mouth should be kept separate from St Lucia; and that the St Lucia system was unable to cope with the quantities of sediment that would be brought in from the Mfolozi system should it be re-linked to St Lucia. This is described in the 1994 Management Guidelines for the St Lucia Mouth, which, with a few changes, sets out the management objectives. This document was ratified at a management meeting shortly after the Mouth closed and all the management actions taken in the Mouth area at the time were within this context. At the end of January 1984 St Lucia was affected by huge floods associated with Cyclone Domoina. The floods washed away the hard structures built to stabilise the mouth and to keep it open. After this Van Heerden and Swart (1996) advised the Natal Parks Board to alter their management strategy and to have a ‘softer’, less intrusive approach that would work with the natural coastal processes.

Figure 1. The Mfolozi and St Lucia mouths – a focus area for management. This photograph shows the confluence of the Msunduzi (bottom right) and the Mfolozi Rivers (centre) which then enter the sea as the Mfolozi Mouth. To the north (top of photograph) is the St Lucia system. Prior to 1950 the Mfolozi flowed into St Lucia at times of drought.

Box 1

The 1986 Mouth Management Guidelines based on the recommendations of Van Heerden and Swart (1996). The recommendations were that:

a) the Mfolozi and St Lucia estuaries should have separate mouths;

b) no hard structures should be constructed at either mouth;

c) a dredge should be used at St Lucia to manipulate the mouth cross-section, and to pump the dredged material to the beach north of the mouth so that sediment would be removed from the system and put back into the longshore drift moving northwards;

d) at times it may be advantageous to the whole system to let the mouth close for periods which could extend for months.

Implementation of the mouth management guidelines would require a hierarchy of management objectives:

The first objectiveis to prevent permanent damage of the system through accelerated sedimentation. The accumulation of sediments is regarded to be irreversible.

The second objective, which is subservient to the first, is to prevent damage that may be evident for several decades, such as the loss of shoreline vegetation through inundation by hypersaline water as this will result in shoreline erosion.

The third objective is to prevent damage that will last for several years – such as that due to the loss of connectivity with the sea; to allow large quantities of salt to accumulate in the system or to prevent the intrusion of salt into freshwater seepage sites along the shoreline.

As the drought progressed, so the management of the Mfolozi Mouth became a concern. Previously little management had ever been applied. Now the mouth threatened to breach into St Lucia. In addition whenever the mouth closed it flooded the upstream farming operations. In the past the needs of the farmers had been given a priority and actions had been taken to prevent flooding. Now the intimate relation between the lower Mfolozi and St Lucia was more evident – and the intrinsic conservation value of the lower Mfolozi swamp was recognised. There was more of a focus on the management of the Mfolozi floodplain than in earlier years.

The concern about sediments dates back to the huge sediment deposits that occurred in the lower portions of the Narrows and the combined St Lucia-Mfolozi bay in the drought of the 1940s to the early 1950s. The dredging of St Lucia was initiated to remove these sediment deposits (Figure 2). Knowledge of sediments is still sparse, and little is still known about how much sediment transported by the Mfolozi will enter St Lucia with the linking of the two systems.

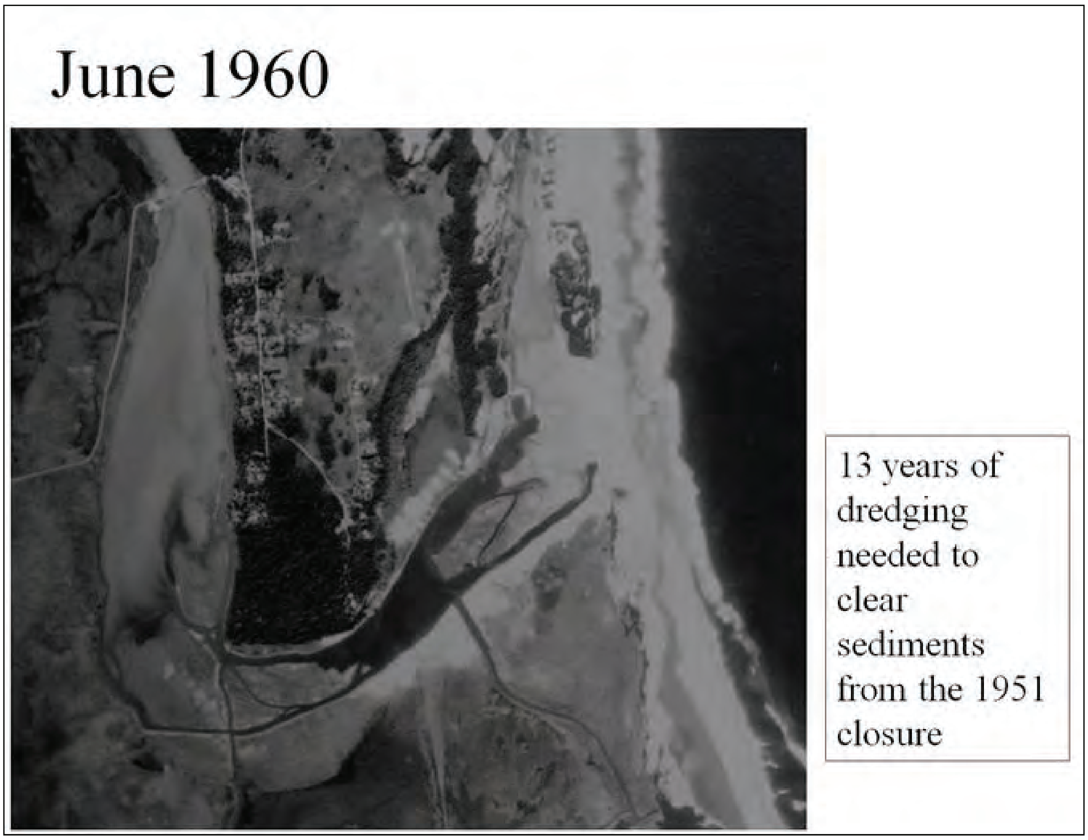

Figure 2. Aerial photograph of the St Lucia mouth taken in 1960 showing the extent of the dredge operations that had started in the mid-1950s. It also shows the extent of the remaining sediments.

Box 2 The 1994 guidelines for the management of St Lucia that were accepted by the Natal Parks Board.

The underlying principle is that St Lucia should be maintained as natural as possible as a viable estuary. Management of the mouth is part of the overall strategy needed to achieve this. The aims are:

1 Except during extreme drought there should be a physical exchange of water between the lake and the sea so that:

- it remains an estuary where there is a mixing of fresh water and sea water;
- fluctuations in salinity are still allowed to occur – in response to wet and dry cycles;
- salinity gradients are maintained in the lake creating a range of aquatic habitats;
- the Narrows is affected by marine tides.

2 Condition of the mouth should not hinder sea-lake movements of animals – particularly during major migrations. But during extreme drought prevention of salinity levels from rising override this and mouth closure is acceptable for several months at a time.

In 2004 the Water Reserve Determination exercise of the Department of Water Affairs highlighted the need for Mfolozi water (Van Niekerk, 2004). This was graphically illustrated when large parts of the St Lucia system dried up as the drought progressed. The Mfolozi 'Indaba' of 2011 again stressed the need for this water to flow into St Lucia (Bate *et al*., 2011). In the meanwhile there was a school of thought that the threat of sedimentation from the Mfolozi River had been too heavily emphasised in the past. This led to a change in thinking described in the Background Information Document (2011) (Box 3) and to the decision to link the Mfolozi to St Lucia via the Beach Canal early in 2012.

Box 3

In 2011 a Background Information document was circulated by the iSimangaliso Authority entitled: Lake St Lucia: understanding the problem and finding the solution (Background Information Document, BID 2011/07).

This document reviewed the state of knowledge of the system and the problems of not having freshwater enter from the Mfolozi River. This is the focus of the GEF funded project that is currently underway. The document provided interim management direction for 2011 to 2012. This is, *inter alia*, to:

a) use and further develop the Back Channel to bring Mfolozi water into St Lucia.

b) allow the Mfolozi to connect up with St Lucia through the natural northward drift of the Mfolozi mouth.

3.2 Sediment trapping in the St Lucia Mouth

Instead of having hard structures to stabilise the mouth, the advice of Van Heerden and Swart (1986) was to dredge a sediment trap at the inland edge of the flood-tidal delta. Its purpose would be to catch marine sediments as they entered the system, and pump these sediments into the sea north of the mouth. By doing so the mouth would be more stable and less likely to drift northwards. This action would also delay the closure of the mouth at the onset of a drought. This removal of sediment in some ways mimics the losses that would have occurred with the natural river flushing processes had the Mfolozi been joined to St Lucia in a combined mouth. This strategy proved to be an effective way to manage the mouth. It did not entirely stop mouth closures and it was accepted that the mouth would still close in droughts. After closure it was accepted that the mouth could remain closed for up to 18 months at a time.

Figure 3. A flood-tidal delta formed by sand brought into the St Lucia system by marine tidal inflows. If the movements of water through the mouth are dominated by river flows in addition to the out-flowing of tides, then this delta does not develop much and the mouth stays open. The sediment trap concept is to trap this sand so that it does not penetrate beyond the inner edge of this delta. (2 August 2007, R Taylor).

Figure 4. The ebb-tidal delta which forms a fan of sediment in the marine wave zone. The slowing of the waves in the shallow water over this delta is evident here as the curved wave pattern in front of the mouth. Note also the spits coming into the estuary on both the north and south banks of the estuary (2 August 2007, R Taylor).

When the St Lucia Mouth closed in 2002, the standard procedure at the time was applied – to continue dredging the sediment basin so that it would be in place when the mouth was opened (artificially) at the time considered best to do so. In March 2003 while this was being done, the dredge hit buried dolosse – remnants of the pre-1984 mouth structure. As a result the sediment basin was moved 50 m to the north.

Once the sediment basin was completed (dredged to a depth of between 6 to 8 m), a 40 m wide channel was dredged seaward into the beach berm, in preparation for breaching. Initially the spoil was pumped northwards and deposited into the sea, and then later into the depression in front of the beach car park and ablution block. After that the dredge spoil was used to block the gap between St Lucia and the Mfolozi to prevent the Mfolozi from joining with St Lucia. Once the sediment trap was dredged to specification further dredging was stopped.

This sediment trap was in place in March 2007, with a channel from it into the beach berm. The combination of extreme tides and high seas and effect of Cyclone Gamede caused the mouth to breach on 2 March 2007. The overtopping sea water was able to erode gulleys into the inland side of the beach berm. It was where these gulleys eroded into the sediment trap that they resulted in the breaching of the St Lucia Mouth. Had the dredged channel and sediment trap not been there it is considered unlikely that the mouth would have breached.

The St Lucia Mouth closed again on 24 August 2007, on a neap tide, after having been open for 175 days. The sand trap did not prevent its closure, but it is thought that it did prevent marine sediments from entering into the estuary beyond the position of the sand trap. Currently the sand trap is still a depression in the estuary bed – but is no longer being maintained. It now serves a useful purpose in capturing the sand being brought in by the Beach Channel that was opened in 2012.

The strategy of using a sand trap is a good one that is far less intrusive than having to dredge large areas of the estuary. It allows for the removal of sediments which mimics the effect of having the sediment flushing capacity of a strong fluvial out-flow that is associated with the Mfolozi when it is joined to St Lucia. It is a system that was implemented after the 1984 floods had scoured away sediment. If, in the future, sediment is allowed to penetrate beyond the sand trap area it complicates dredging as the spoil then has to be deposited on the banks of the estuary or much longer dredge pipes with a booster system would have to be used to pump the spoil into the sea. The managers need to be aware of these longer-term consequences when planning a minimum interference strategy.

3.3 Keeping the St Lucia and Mfolozi mouths separate

The 1994 Mouth management guidelines (Box 2), ratified by the Board of the Natal Parks Board, stated that the St Lucia and Mfolozi Mouths should be kept separate. In September 2001 the two mouths had been joined for some time. The dredge was being used to maintain the sediment trap and the spoil was being pumped via the land line into the sea north of the mouth. At its November 2001 meeting the Mouth Management Committee reaffirmed the mouth management guidelines adopted by the Board of the NPB in 1994 and took the decision to separate the Mfolozi from St Lucia.

The implementation was planned so that the first step was to block the connection between the Mfolozi and St Lucia mouths. The second step was then to cut a new Mfolozi Mouth near Maphelane. The dredge spoil, coming from the sediment trap, was deposited in the Mfolozi channel and eventually the Mfolozi was closed near St Lucia (after three tries) and its new mouth breached near Maphelane on 19 March 2002.

Then in 2005, the northward moving Mfolozi Mouth was again threatening to breach into St Lucia. This was again considered to be undesirable and in August 2005 a separating wall was built on the beach to prevent Mfolozi entering St Lucia. By May 2006 the Mfolozi Mouth had once again been successfully closed and a new mouth opened near Maphelane. This had been a very large job. The closure of the Mfolozi near St Lucia was implemented using the dredge, two large bulldozers and an excavator. Some equipment was hired from UCOSP, and some from a private contracting company.

The objective of separating the Mfolozi from St Lucia was successfully achieved on both occasions. A large amount was learned about the closure of the Mfolozi. Future work on the Mfolozi was done with knowledge of the rate that the Mfolozi mouth drifts northwards. This gave more time to achieve the objective. A lot of technical expertise was gained. Closure was effected at neap tides when there was the least tidal range. It was also done when there was very low flow in the Mfolozi. The closure of the Mfolozi in 2002 may have contributed to the closure of the St Lucia Mouth by removing the fluvial flows that take out sediments. But this is considered to not have been the case as the combined mouth was so far to the north and was already on the verge of closing. It was also during a period of very low flows in the Mfolozi River.

3.4 The decision not to open the closed St Lucia mouth

The 1994 Mouth management guidelines, ratified by the Board of the Natal Parks Board, stated that the St Lucia and Mfolozi Mouths should be kept separate. In its November 2001 meeting the Mouth Management Committee reaffirmed the mouth management guidelines adopted by the Board of the NPB in 1994. Then, in June 2002 the mouth closed and was left closed. According to the mouth management guidelines the mouth should be breached within 18 months of closure. The closed condition was reassessed in March 2003 and the decision was taken to leave the mouth closed until conditions 'return to normal'.

In March 2004 the EKZNW and the Wetlands Authority, jointly took the decision that the mouth of St Lucia was to remain closed until there was an adequate head of water so that, when it was breached, there would not be a large influx of sediments from the sea. It was accepted that it could remain closed for another year or two. This was said with the knowledge that if the mouth was open it could bring in a lot of sediment (from the sea) and that it would bring in seawater which would replace evaporation and increase the salt load in the system. This decision was taken in the context that the St Lucia and Mfolozi Mouths should be kept separate. This decision was to guide much of the management over the next few years.

Not opening the mouth was in line with a minimum intervention policy. It was also realised that with the mouth either open or closed there would be undesirable consequences if the drought persisted. The decision not to allow Mfolozi sediment to enter the system was upheld, and methods of getting sediment free Mfolozi water into St Lucia were pursued.

In September 2002 the ship *Jolly Rubino* was offshore of the KwaZulu-Natal coast when it caught fire. The fire could not be contained and the crew abandoned the ship. It drifted inshore and stranded on the beach near Cape St Lucia south of Maphelane. To prevent any infiltration of its cargo of oil and chemicals into the Mfolozi River and St Lucia Estuary the authorities closed the mouth of the Mfolozi with floating oil containment booms. This was over the equinox spring tide period when pollution penetration into the estuary could have been large, and overtopping of the beach could have occurred. On the beach a sand wall was pushed up with bulldozers – a 2 km long wall to protect St Lucia and the Mfolozi. This wall proved to be controversial as some members of the public blamed it for keeping the St Lucia Mouth closed. With time the wall – a low ridge of sand – was flattened and dispersed by wind. The effectiveness of these actions was not tested as no pollutants came on to the

St Lucia beach. However it was a precautionary exercise for something that could have caused extensive environmental damage.

3.5 Northward movements of the Mfolozi Mouth

As the management of the St Lucia system is dependent to a large degree on the configuration and location of the Mfolozi and St Lucia mouths, it is important to know as much as possible about how they behave. With the St Lucia Mouth closed, it provided easy access to the Mfolozi Mouth by travelling down the beach to it from St Lucia. During this drought period a considerable amount has been learnt about how the mouth functions, and the technical aspects of its management.

The location of the Mfolozi Mouth is measured at regular intervals by walking along its northern shoreline and using a GPS to plot its position. Successive tracks are downloaded onto a Google earth map and the distance the mouth has moved in the interval between plots is measured. This is then expressed as a graph to provide the average distance moved per day (Table 1). As the rate of movement is reasonable constant over each period, it provided a useful tool to predict the location of the mouth at some future date. The difficulties in 2004 and 2005 were a result of the maintenance work being left too late – until the Mfolozi was close to joining with St Lucia. The resulting job was done in a rush and hence not being done under optimum tide and sea conditions. Knowledge of when the Mfolozi would approach St Lucia gave the managers sufficient lead-in time for budgeting and addressing equipment needs.

Table 1: Records of the rates at which the Mfolozi Mouth has moved northwards during the period of drought.

Date at end of period	Period of measurement (days)	Average rate of movement (m/day)
August 2005	79	2.1
October 2006	265	2.8
January 2007	?	1.9
November 2007	524	1.7
Feb 2010	200	1.7
Nov 2010	?	3.08
Feb 2012	?	2.9

The monitoring was effective in providing management with information needed to manage the mouth, but it has not informed us about the processes that cause the northward movement. It is strange that the rate of movement for a specific period is very constant, but between different breaching events can differ from 1.7 m to 3.08 m/day. This is unexplained, but is likely to be due to the location on the beach as well as the quantity of sediment on the beach berm.

A large pile of dredge spoil that rises to above 5 m above mean sea level was deposited on the south bank of St Lucia close to the beach after the Mouth closure in 1952. In the 1984 floods this spoil blocked the seaward free-flow of floodwaters possibly increasing the amount of flow that was diverted into St Lucia at the time. This pile of spoil now interferes with proposed management activities. It forces the Beach Canal to be very close to the sea. It is a remnant of past management activities that will affect the future efforts to join the St Lucia and Mfolozi Mouths.

3.6 Management of the Mfolozi Mouth

During the drought period the Mfolozi Mouth closed naturally or was closed artificially on several occasions. It also breached naturally or was breached artificially (Table 2). The management of the Mfolozi Mouth was directed, at first, by the objective to keep it separate from the St Lucia Mouth, then later by the additional objective to allow Mfolozi water to back-up so that it could flow through the Back Channel into St Lucia. Management of the Mfolozi Mouth was also at times implemented to relieve back-flooding which prevents drainage of the lower sugarcane farms.

The management of the Mfolozi Mouth met the defined objective of not allowing the Mfolozi to join with St Lucia. In implementing the management the Dredge Unit gained expertise in working on the beach and with the river. The work done did require a high level of intervention, but in the dynamic beach environment there appeared to be no long-term damage.

The understanding gained of the functioning of the Mfolozi Mouth is encapsulated in the guidelines for the Mfolozi Mouth given in Box 4

Table 2. Dates of opening and closing of the Mfolozi Mouth.

	Closure		Opening		
Date	Natural	Artificial	Natural	Artificial	Comment
2004	20 July			30 July	
2005		March / April, actual date not recorded		March / April	Mouth moved. This is the last time closed then opened immediately
2007	End July		29/30 August		Opened over spring tide
2008	March (?)			June	On closure, cut a weak link on beach – but did not breach then. Water via Back Channel ~3 million m^3
2008	31 May			5 December	Brought in about 17 million m^3 of water
2008-2009	26 Dec 2008		8 Jan 2009		
2009	August / September				Open about 5 December
2009-10	26 Dec 2009		8 Jan 2010		Opened when flows in Mfolozi suddenly increased
2010	24 April			14 May	Breached after flooding farms
2011	?			22 July	Breached after flooding farms
2011	4/5 September			24 October	Breached – but then closed again immediately
2011	9 September			9 November	

Box 4

Conditions which promote natural closure of the Mfolozi Mouth:

- Low river flows.
- Little tidal range (e.g. at neaps – especially equinox tides).
- Accumulated sand off the mouth (ebb-tidal delta) and on beach.
- Accumulated sand in flood-tidal delta (causing shallowing of mouth and restricting inflows).
- Mouth has drifted far north (decreasing the hydraulic gradient).
- Storm conditions at neap tide – creating waves that deposit sediments on the beach - and block the mouth.
- Possibly a north wind which prevents the draining of the estuary by pushing water up the Msunduzi.

Conditions which keep the Mfolozi Mouth open:

- High river flows.
- Large tidal range (e.g. at springs – especially equinox tides).
- Marine currents that wash away sand from the ebb-tidal delta.
- Wave overtopping which increases water outflows from estuary.
- Strong out-flowing currents reduce the flood-tidal delta (i.e. a fluvial dominance).
- Mouth close to Maphelane resulting in the steepest hydraulic gradient.

(From the Mouth Management Meeting of 27 February 2010)

3.7 Investigations to bring in Mfolozi water

It was realised that St Lucia needs freshwater during periods of drought, and the best place to gain that water is from the Mfolozi River. Early in the drought an assessment was made of the three options for routes to bring in water from the Mfolozi, *viz* via the Link Canal, the Back Channel and a channel behind the beach berm (the Beach Channel). The pros and cons of each were discussed. The Beach Channel strategy was discarded at that time as a possibility and further investigations were made into the use of the Link Canal and the Back Channel.

Figure 5. The superstructure for the flood protection gates at the Intake Works at the start of the Link Canal (November 2006, R. Taylor).

3.7.1 Assessment of the Link Canal

The Link Canal was built in the early 1980s to bring water into St Lucia from the Mfolozi. It has a structure with sluice gates on the Mfolozi to bring water in only at low flows when the river contains relatively little sediment. The project was close to completion when the 1984 floods filled the excavations with sediment and damaged the canal. At that stage the canal was not needed as St Lucia was in a wet phase, so the canal was ‘put in cotton wool’ by being blocked by several cross-berms.

To assess the potential to use the canal the Intake Works were cleared of vegetation in 2005 and some work was done to see what would be involved in removal of sediments. In addition a model to simulate the influence that the introduction of Link Canal water would have on St Lucia was developed. Simulations were done with a variety of quantities of water and also to see if the Mfolozi could provide such water. The conclusion was that the water would have a significant beneficial effect on South Lake (Kelbe & Taylor 2005).

It was estimated that the cost to reinstate the Link Canal would be between R500 000 and R750 000. In May 2006 the decision was taken not to reinstate the canal. This decision was partly based on the concerns that there would be erosion of the banks of the canal and partly on the concerns about possible socio-political difficulties relating to its daily operation. These related largely to access to the Intake Works through an area where there were ongoing land disputes. Restricted access would have meant that the canal could not have been operated properly.

In 2002 there was concern about the proximity of a large meander in the Mfolozi River that was close enough to break into the Link Canal. Then in January 2004 Mfolozi water overtopped into the Link Canal during a flood, and this happened again in 2005 and a few times in 2007. This was partially due to the development of the flood diversion weir at Riverview. This controls the amount of flood water that can pass down the canalised Mfolozi River. It is designed to divert water that exceeds the quantity that the canal can cope with – and hence protect the canal from breaching. However, the amount of water passing down the canalised Mfolozi is greater than what the Mfolozi River can carry downstream of the canal. The excess water burst out of the Mfolozi – and in this case flowed into the Link Canal. During the past decade there have been several occasions where there has been overtopping of the Mfolozi while in flood into the Link Canal. This has brought a significant amount of water into the canal and St Lucia especially at the end of the drought in the summer of 2012 to 2013.

On several occasions during the drought period the need for flood protection of the Link Canal was discussed. The problem is becoming more immediate. A possible short-term management intervention that was considered would be to block the outlets of the Link Canal at Honeymoon Bend and where the canal passes under the Mtubatuba-St Lucia road. These actions would slow flows in the canal during floods. This is an issue that will need to be addressed comprehensively in the future.

3.7.2 Transferring Mfolozi water into St Lucia via the Back Channel

The Back Channel is a canal that was excavated to bring Mfolozi water into St Lucia at the peak of the 1968-72 drought. At the time it had very little success because the St Lucia and Mfolozi Mouths were either open for all, or for some of the time when the managers tried to use it. Subsequently it was blocked off with a cross-berm that was renovated after the 1984 flood. The margins of the Back Channel accumulated sediments and only a narrow central channel remained. The lateral sediment deposits were colonised by mangroves.

By 2005 the wall of the cross-berm had been breached by hippo moving over it. Sea water entering the Mfolozi Mouth was coming into St Lucia via the Back Channel. When the Mfolozi Mouth closed in July-August 2007 it was noted that fresh Mfolozi water was also diverted through this channel into St Lucia. Flows in the Mfolozi River were low and all the water it contained was coming through into St Lucia. This was a fortuitous observation of an event which was to be repeated, with some management assistance, over the next few years whenever the Mfolozi Mouth closed.

In March 2008 the mouth of the Mfolozi River was threatening to breach into St Lucia. To prevent this it was closed by the managers. Prior to this, after a closure, the standard procedure had always been to immediately open a new mouth near Maphelane. This was not done in this case. With no exit to the sea, the Mfolozi River water backed up in the swamps raising the water level. This resulted in the flow of the river water, through the Back Channel, into St Lucia. The canal was operational for 203 days in which time it carried an estimated 17 million m^3 of Mfolozi water into St Lucia. This is a relatively small quantity – but significant as it was the equivalent of having a large and widespread rainfall event over St Lucia. It also was sediment-free water as the sediments had settled in the flooded lower parts of the Mfolozi floodplain. Using the Back Channel in this manner created the mindset that it was feasible to bring Mfolozi water into St Lucia. The problem was that the backed-up water affected upstream sugarcane farming operations due to flooding.

Reviewing the progress with this at a Mouth Management Committee Meeting in August 2008 it was agreed that this water was very useful, but not enough. The low-resolution monitoring that was being done showed the relationship between the level of the backed up water in the Mfolozi Flats with the amount of flow in the channel. The higher the water level the greater the flow. But also, the higher the water level, the greater the area of floodplain that was flooded and the more it affected sugarcane farming operations.

The farming was affected in two ways: Firstly, the lower fields in the CotCane area have one-way ‘flap-valves’ to allow an outflow of water from the internal drainage canals into the Msunduzi River. These valves rely on low water to drain the canals – as occurs at low tides. The valves then close at high tides preventing a reverse flow of the Msunduzi water into the canals within the sugar fields. So any closure of the Mfolozi Mouth that prevents tidal action affects this draining of the fields. Secondly, the fields to the north of the CotCane area drain via the Main Drain. Most of these fields have no structures to control back-flooding, so when the Msunduzi rises they become waterlogged.

Monitoring the operation of the Back Channel provided insights into how it functioned. The main parameters controlling the amount of flow through the Back Channel were found to be:
The quantity of water flowing in the Mfolozi River. If this was greater than what the channel could carry then water level in the lower Mfolozi floodplain area would rise.
The dimensions of the Back Channel control the amount of water it can carry. It originally was excavated to be a 40 m wide canal. Now there is only a single central channel that is about 3 m wide and 1.2 m deep (it varies). The silted flats on either side of the channel are colonised by *Avicennia marina* mangroves. During low levels all the water is carried via the central channel, but when the water is high it floods the lateral mangrove areas and a slow flow of water occurs here. Water in the deeper channel moves faster.
The feature that controls the quantity of water flow through the channel is an elevated area of sediment deposits at the St Lucia end of the channel. This acts as a 'spillway' which controls the total amount of water that can flow through the Back Channel at any given water level.
Thus, the higher the level of the backed up water in the lower Mfolozi floodplain, the greater the flow of water through the Back Channel. There is an exponential relationship between the level of the backed up water and the amount of flow in the channel. At its peak the flow is approximately 5 $m^3 s^{-1}$.
The volume and area of backed-up water on the floodplain acts as a stilling basin allowing Mfolozi water to drop its sediment load.
The sediment load carried in the Mfolozi River is related to the speed of the flow. When this reaches the backed up water in the lower floodplain, the longer it takes to pass through to the Back Channel, the greater the proportion of sediment that can settle.
The height of the beach berm controls breaching of the Mfolozi River to the sea. Breaching of the Mfolozi is effected when the water behind this beach berm rises to the level where it overtops and erodes a path to the sea. A large storage area in the lower Mfolozi floodplain will absorb the quantity of water from a small flood without breaching seaward. After such a flood it is important to slowly reduce the amount of Mfolozi water 'in storage' so that the floodplain can then accommodate the next spate in the Mfolozi without breaching. This can be done by encouraging the constant drainage of the floodplain via the Back Channel into St Lucia.

Using the available topographic information (which was sparse) a digital elevation model of the lower Mfolozi was made, and a first step of a water balance model was drafted (Kelbe & Taylor 2011). With this knowledge the recommendation was made to increase the amount of water that the Back Channel could carry by excavating a second outlet to the Channel. This was done in September 2011. But it was also recommended that a "V"-notch weir be constructed to allow more drainage of the 'floodplain storage area' during periods of low Mfolozi River flows. This was not implemented.

A further enhancement would have been to construct a very much larger channel outlet that goes through the dredge spoil pile at the St Lucia mouth. This would have been designed to handle large quantities of water. This still has possibilities for future consideration. It is a design that allows for sediment settling in the lower Mfolozi floodplain as well as allowing the largest of floods to breach directly into the sea. It is a 'soft' engineering approach. It also has the advantage of removing some of the pile of accumulated spoil as it is excavated.

This operation of the Back Channel was a very successful exercise although it only brought in a small amount of water. It showed that Mfolozi water, without sediments, could be successfully transferred into St Lucia. What was also important, but not fully realised at the time, was its importance as a biological conduit bringing biota from the sea into St Lucia.

In hindsight the Back Channel exercise was a good example of adaptive management. Progressively, as the channel was used, so an understanding of the processes involved was gained. The Mfolozi mouth was managed better, the second mouth to the Back Channel was excavated to increase channel flows, research projects were initiated and this was the main instigator of a lot of the focus on the Lower Mfolozi Floodplain. The "V"-notch weir was never constructed and the enlarged channel suggested by Kelbe and Taylor (2011) was never really considered. However, the Back Channel, with its original outlet as well as the new enlarged outlet, still functions. Every spring tide, when the Mfolozi Mouth is open, there is seawater input. This is an important contributor of marine life entering St Lucia.

UCOSP had recommended that the park managers enlarge the Back Channel. This was not done as it would have meant that the channel would have lost the backing up of water into the 'storage basin'. This effectively would then have functioned as the present day Beach Channel functions – with no barrier to flows from the sea, and no settling of sediment in the lower Mfolozi.

3.8 Construction of the Beach Channel

Recently (2012/2013) it is no longer regarded as very important for the Mfolozi water being brought into St Lucia needs to be sediment-free. This change in thinking was behind the excavation of the Beach Channel which allows Mfolozi River water to enter St Lucia without any backing up or dropping of sediments. This Beach Channel only functions effectively if the Mfolozi Mouth is closed.

In February 2012 the Beach Channel was excavated immediately behind the beach berm to link the Mfolozi to St Lucia. It was hoped that the Mfolozi Mouth would migrate northwards to link into this channel. However in early March the area was affected by the close proximity of Cyclone Irina. Its winds and associated waves affected the Mfolozi Mouth. Waves overtopped the berm to the south of the Mfolozi Mouth and caused it to create a new mouth some 300 m south of the existing one. The connection of the Mfolozi via this channel was finally effected on 6 July 2012.

This management intervention has not been in operation for long enough to assess its effectiveness. The situation changed with the breaking of the drought in early September 2012. Since then there has been regular and abundant rainfall at St Lucia and in its catchments. All the rivers have been flowing strongly for the full summer period. So at this stage, little can be said of the effectiveness of this intervention as it has not been tested under the conditions it was designed for.

3.9 The release of crocodile hatchlings into St Lucia

A biological management intervention was that of the release of crocodile hatchlings into the system. In November 2009 some 300 crocodile that had hatched at the Crocodile Centre in February 2009 were released in various localities around St Lucia. Each crocodile was scute-clipped for individual recognition. The objective of this release was to counter the low nesting rate of the previous years. It was also to act as a mark-recapture experiment for the Zululand crocodile Research Programme to gain an understanding of the behaviour of young crocs.

Was the population depressed as a result of less nesting? There would have been fewer eggs – but it is not known if the fecundity was different and whether the drought conditions with good emergent vegetation along the shorelines resulted in lower hatchling mortality and better than normal feeding. Simulations generated from detailed population modelling compared to count data may at some later stage indicate the success of this attempt to boost the croc population. There were few resightings of hatchling crocodiles – so the second objective was not successful

3.10 Management of fish stocks

At the Department of Water Affairs Reserve Determination meeting in 2004 it was identified that one of the threats to the integrity of St Lucia is overfishing. The main problems are extensive illegal netting of fish and prawns.

During the early stages of the drought the prawns, possibly confused by changing salinity gradients, accumulated in the Nyalazi River where they were caught in large numbers. The value of illegal prawns is large, making prawn poaching a lucrative business. The Anti-Poaching Unit had several successful convictions of prawn poachers, but poaching was only reduced when the prawn stocks declined. Similarly, mullet, and later Tilapia were netted. The main areas where netting occurred were in the North Lake and the lower Narrows.

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In 2003 excessive numbers of kob were being caught by anglers in the reduced volume of the lake. A ban on the capture of kob in the system was implemented. The purpose was to preserve kob stocks that were being excessively caught. It turned out that most of the kob in St Lucia would have died out as a result of hypersaline conditions and drying up of lake basins. The ban is still in effect, so it will preserve any kob that come into the system at this stage.

3.11 Gardening and agriculture in the lower Mfolozi Swamps

Due to the drought, the Mkhuze and Mfolozi Swamps became more accessible to people wanting to farm there. The rich soils, which are waterlogged in wet years, became more accessible, as did paths to walk or drive into the swamps. Initially in both areas farming was of small areas where subsistence multi-cropping occurred. With time this changed to large areas being planted to monocultures of commercial crops.

The small-scale farming had little impact on the system when there were few farmers, but as it became more intensive, so the impact was larger. In the lower Mfolozi floodplain area, which is within the iSimangaliso Wetland Park, tracts of swamp forest have been felled. In the Mkhuze Swamp, which is land under Traditional Authority control, there is commercial planting of sugarcane. This is in wetlands that prior to this drought had not been cultivated. These instances are manifestations of the threats related to increasing numbers of people along the boundaries of the park. These are people who want to make use of what they see to be unexploited resources within or adjacent to the park.

4 ECOLOGICAL RESPONSES TO DROUGHT – WHAT WE HAVE LEARNT

4.1 Knowledge retention

Zululand is prone to droughts which are part of the natural variability driving the ecological dynamics of the region and the natural systems are adapted to cope with the extreme conditions. However, human impacts aggravate the drought conditions. River flows are reduced by loss of wetlands in the catchments; flows are intercepted in farm dams and in large dams; irrigation increases water lost through evaporation; and afforestation increases transpiration losses. The catchments in KwaZulu-Natal are steep and normally shed a lot of sediment, but this is accelerated by poor catchment management practices. St Lucia, being at the bottom end of the catchment is affected by the reduced water inputs and the accelerated sedimentation.

Drought affects the terrestrial areas adjacent to St Lucia by lowering the groundwater table and drying the pans. It affects the swamps by desiccating the peat and making them prone to peat-fires. It affects the water balance in the estuarine system where evaporation exceeds freshwater inputs. It affects the mouth dynamics by altering sediment erosion and deposition patterns which affect mouth closure. In St Lucia drought has system-wide impacts as well as focused impacts on components of the system.

To understand the impacts of drought we usually look at the affected ecosystem components. During each drought knowledge and experience is gained but not transmitted effectively to managers and researchers in the next drought. The time spans are such that there is seldom continuity with the same people being in the area for successive drought periods. As a result informal knowledge is lost. The problem is how to record this knowledge so that it is of use to future managers.

The knowledge can be recorded as guidelines and policies – which do not encapsulate the understanding that has been used in their development. Alternatively the knowledge can be recorded in models. These can be in the form of conceptual models – verbal descriptions of our understanding of how the system functions and responds to specific conditions. Or the knowledge can be encapsulated in more formal representations such as expert systems and computer-driven models. We are not yet at the stage where we have the capacity to do this to any large degree, but we do need to start accumulating the understanding that will be embedded in these models.

Drought responses of components of the system provide insights into the processes that drive the full ecosystem. These insights are in different forms. There are the expected responses which we understand and can model. There are also, the unexpected responses which, with hindsight, we could have predicted. If we record these responses they can be incorporated into models for future information. And finally there are also the stochastic events; which make sense when looking backwards, but as these are random events which could not have been predicted they cannot be modelled unless we have good knowledge about their frequency of occurrence.

This section of the report records some of the informal knowledge gained during this drought – especially that which is in the second category of knowledge, that which is obvious in hindsight. This section does not aim to review the more formal scientific findings that are recorded in scientific publications.

Figure 6. Succulent salt-marsh at Charters Creek. The abundant growth is a rapid response of the plants to colonise the vacant habitat which is available as the lake level recedes.

4.2 Hydrology and patterns of drying up of Lake St Lucia

Figure 7. At the peak of the drought the whole of the North Lake dried up. A field ranger walks across the dry lake bed in the Selleys Lakes area. (Photo C Dickson).

One of the most spectacular features of the 2002 to 2012 drought was the drying up of large portions of the lake basin. At its most extreme about 80% of the system was dry. From the start it was appreciated that by leaving the mouth closed the water level would drop and result in a reduction in the lake surface area. But, without the addition of freshwater to replace water lost to evaporation there is a loss in water volume. If the mouth is closed then the water level drops or if the mouth is open, the water lost is replaced with sea water. If it is replaced with sea water then the quantity of salt that enters the system will build up and may take years to flush out at the end of the drought. Both scenarios lead to extreme ecological conditions. For this drought the management option was to keep the mouth closed.

As St Lucia dried up, the shallow parts of the lake dried first as expected. But the effect of this was not fully appreciated until water levels dropped exposing large sections of the North Lake. As water receded, so the wind would push it onto and off shallow low-gradient areas of lake bed. This wind-blown water was prone to heating or cooling – depending on the ambient temperature and irradiation at the time. With the change in wind speed or direction it would then be brought back into the main body of the water – causing rapid temperature changes. This water on the shallow flats also evaporated, causing precipitation of salt on the surface of the mud.

As the lake water level dropped it exposed various topographic features of the basins. These included the underwater dunes in eastern Catalina Bay, the straight line 'drop-offs' in the Catalina and in Tewate Bays. Rocks were exposed in places along the Dead Tree Bay shoreline, the Brodies Shallows area, south of Charters Creek and the rock outcrops off Hells Gates that were later used as breeding sites for pelicans, cormorants, gulls and Caspian terns. Sand spits were also exposed off Vincent and Lane Islands. The lowering of the water highlighted how poor our bathymetric maps of the system are.

The classic geomorphological 'segmentation' of coastal lagoons was displayed as the water level dropped. This left a few of the deeper basins holding water, each separated from each other. These were those of Tewate Bay, Dead Tree Bay, Catalina Bay, Makakatana Bay and the Narrows. The evolution of coastal lagoon systems causes a progressive 'shutting down' of such compartments as the system gains sediments and changes from a deep estuary to a coastal floodplain. Already, in the St Lucia system, the Mkhuze Swamp basin and the Mfolozi floodplain basin have reached the coastal floodplain stage. This drought showed us how close we are to having parts of the North Lake transform into a similar system.

As the drought proceeded, we learnt about the very important sand bar that stretches from the western tip of Makakatana Bay to the northern Makakatana Peninsula. At low levels this sand bar functions as a natural "spillway" separating the Narrows from South Lake, and allowing only northward flows of water. The Narrows had an excess of water most of the time and this 'spillway' regulates the water to a fairly constant level in the Narrows. This has been an important feature. Without this "spillway" effect the water level in the Narrows would have settled to that of Catalina Bay and the launch tours from St Lucia would have been 'grounded' for much of the drought. It was fortuitous that the dredging of the Narrows, from the mouth to the lake, in the early 1970s did not go this far upstream. The plan had been to have a relatively deep channel all the way from the mouth – but the dredging was stopped a short distance before it reached this important Makakatana sandbar.

During this drought a considerable amount was learnt about the role of the lower Mfolozi floodplain in the functioning of the greater St Lucia ecosystem. As we 'experimented' with bringing water into St Lucia from the Mfolozi via the Back Channel whenever the Mfolozi Mouth closed, so our understanding of the processes became clearer. When the Mfolozi closes, if there is not free-flow into St Lucia, then the water backs up in this lower part of the floodplain. It forms a stilling basin in which sediments settle and the water that is able to overtop into St Lucia (via the Back Channel) is sediment-free. The sediments in suspension settle very rapidly when the water is still – possibly because most of the sediment is in the 'silt' size category, and not 'clay'.

A better understanding was also gained of the sugarcane farming activities in the lower lands and how the farms rely on low-water conditions (e.g. low tides) to empty the farm drainage canals. The lower farms were very badly waterlogged by the developing policy of not allowing the Mfolozi Mouth to be breached immediately after closure.

4.3 Spatial and temporal patterns of salinity

When St Lucia closed in 2002, the average salinity throughout the system was about 15 ppt which translated to a mass of about 5 million tonnes of salt in the entire system. It was assumed that, with the mouth closed and no water coming in from the rivers, the wind-driven lake circulation would even out the salinity gradients and the lake would have a homogenous salinity. This was incorrect. As the northern parts of the lake are shallower than the southern parts, they have a much larger evaporative area relative to water volume. This caused a faster concentration of salinity there than the currents could redistribute. In addition, as water level dropped, so the friction to water movement increased aggravating the situation by impeding circulation. These effects resulted in the formation of a strong salinity gradient in the system – with it being most saline in the north where the lake is shallowest. This gradient was enhanced by having low-salinity water enter the South Lake from the Narrows. This is because more freshwater enters the Narrows than is lost to evaporation. Water from the Narrows (containing salt) moved northwards as there was freshwater input from the Mpate River, and the Oxbow and Dukuduku Streams. This resulted in a slow loss of salt and the Narrows became fresher as the drought progressed. Salinity was reduced to about 3 ppt near the end of the drought. This is important because this formed a plug of freshwater which is likely to affect the movements of biota once the estuary-sea connectivity is fully restored. This plug of freshwater is a situation that will occur whenever a combined St Lucia-Mfolozi Mouth closes and Mfolozi water is diverted into St Lucia. This was the situation recorded in the late 1940s, and at that stage having too much freshwater coming in from the Mfolozi was one of the arguments for separating the Mfolozi from St Lucia. What they saw was a natural process that the managers of the time did not understand.

The big fear, based on what happened in the 1968-70 drought, was that hypersaline water would be washed onto shoreline vegetation if the water level in the lake was both high and hypersaline. In the 1970s this process killed the shoreline vegetation and caused severe erosion of the shoreline of the lake and its islands. Although hypersaline conditions have occurred in the 2002 to 2012 drought, water levels were low. Thus the salty water was not in contact with shoreline vegetation which remained healthy for the duration of the drought. In areas where there was groundwater seepage pools of water of varying salinity formed along the shorelines.

Another fear is that if too much salt enters the system during a drought, then it could take years for the salt to flush it after the termination of the drought (unless the drought ends with a flood). In the 6-month period that the mouth was open in 2007, the mass of salt in the system doubled. The lesson we learnt after this was how much more rapidly parts of the system reached hypersaline conditions with the higher salt load in the system.

As the drought progressed and water level dropped, the lake separated into discrete compartments. Each compartment then had its own unique surface area: volume ratio – and hence behaved differently.

Salt in an estuary exhibits conservative behaviour. In other words, what is locked in the system at closure stays in the system. However some of the salt is locked into the sediments in the drying process, some of the salts that precipitate do not re-dissolve easily, and some salt is lost as a component of the dust blown out of the system. This was discussed by Bate and Taylor (2008). The consequence of the salts either being locked up either in the mud or as a precipitate and the wind-blown losses meant that on filling up the salinity in the system is lower than expected.

The physics, chemistry and biological impacts of hypersalinity are subjects that require more investigation at St Lucia. Extreme hypersalinity has been a feature of St Lucia during droughts and we do need to have a better understanding of the processes associated with it and the effects of it on plants and animals. The research of Carrasco and Perissinotto (2012) indicates that few, if any, animals can survive above 130 ppt, but below this there are some organisms that thrive – and these form a very simplified food web. There does not seem to be the recognition that the different salts precipitate out at different salinity concentrations which could have interesting physiological consequences for the biota. This is a research field that could be pursued experimentally or during the next hypersaline period.

The reporting of salinity concentrations in the lake system when parts are hypersaline has been misleading. It is human nature to stress the most extreme conditions. Often the statement was made that salinity was, say, 200 ppt in False Bay – but seldom was it mentioned at the same time the salinity in the Narrows was 3 ppt. These are both extreme conditions for estuarine life. The lesson to learn from this is that a more even reporting of salinity needs to be given – possibly giving the full salinity range and an average that is representative for the full lake or alternatively presenting salinity for the different estuary compartments.

4.4 Sediments and mouth dynamics

Possibly the most important field of research that has been neglected is that of sediment dynamics. St Lucia is a coastal system that has the evolutionary trajectory of changing from a deep-water lagoon to a coastal floodplain. This occurs as it accumulates sediment (and to a lesser extent in response to changing sea levels). So much of the dynamics of the present system is related to sediment, and many of the management concerns are linked to the processes affecting sediments and how the St Lucia and Mfolozi Mouths respond to this. Yet we still know very little about sedimentary patterns. There is still concern whether the quantity of sediment carried by the Mfolozi River will adversely affect St Lucia with the reconnection of the Mfolozi to St Lucia. We know little about the distribution of sediments within Lake St Lucia.

Natural breaching of a closed St Lucia would have occurred in the past whenever water level was high enough to overtop the beach berm. This would have caused a catastrophic flushing event, taking with it a lot of the sediment accumulated in the mouth. Similar flushing could also have occurred as mega floods scoured their way to the sea, as happened in 1984. Understanding the flushing of sediment by the mega floods and, especially, the mega breaching events has helped us to understand the sediment dynamics of the area. It also has become clear that the huge sediment quantities of the 1950s (which took 13 years to dredge away) were largely marine sediments being brought in on the flood tide (Taylor 2013). At the moment most of our understanding of these processes is conceptual. We have little empirical knowledge of the actual behaviour of sediments that enter a joint St Lucia – Mfolozi Mouth system. It is likely that sand accumulations (from the sea or from Mfolozi bed load) would affect the physical mouth processes. On the other hand, the silt, either when in suspension or settled on top of this sand, would have its main effect on biological processes.

It is easy to understand that the breaching would be caused by overtopping, but does breaching also happen naturally by erosion of the seaward side of the beach berm by wave action? Is this erosion enhanced by saturation of the beach berm with groundwater if the estuary is above mean sea level? These are questions that have not been answered for St Lucia. In 2007 high seas breached the mouth of St Lucia – but this is likely to have happened only because the dredge had excavated a sediment trap into the beach berm. This made the beach narrower at that point with a steeper inland slope. The erosion was not on the seaward slope of the beach, but was caused by the landward flow of overtopping water which eroded gullies in the back-slope of the beach.

During the period that the St Lucia Mouth has been closed we have learnt a lot about the behaviour of the Mfolozi Mouth. On several occasions we have monitored its northward progression and have shown how constant this can be. There is now a better ability to predict its rate of movement and also when it is close to closing (see Box 4 and Table 1).

There is a perception that this may have been a drought effect, with more closures because the river flows were so low. On the other hand the closures could also be due to an accumulation of sediments in the mouth area.

Within the lake, when water levels were low or the bed was dry, a different set of geomorphological drivers come into play during the drought. The sediments were exposed to wind-driven processes. In many places the lake edge of St Lucia used to be steep as a result of wave-cutting where there was no vegetation protection. With a lowering of water levels, dry sediments have been shifted by wind. The steep margins to the lake basin have filled with sediment and now are gently sloping. These margins have been colonised by plants, and now that the lake is full there is a wider band that can be inhabited by shoreline vegetation. The band of shoreline vegetation is more protected from wave action – by the plants and the gentle slope, and now is one of the most productive habitats within and estuary.

In places wind-blown sand has accumulated against patches of vegetation in the dry lake bed – forming hummocks of wind-blown sediment. We have no idea of how much wind-blown sediment was exported from the dry areas of the lake. At times there were dust storms and people in the village of Hluhluwe, almost 10 km from False Bay, complained of the increase in dust there.

4.5 Estuarine vegetation

With the exception of the mangroves, which retained their *status quo* but had little recruitment, and *Zostera capensis*, which may have died out, the estuarine associated vegetation thrived during this drought period. The wide beaches and large areas of exposed habitat resulting from the low lake levels created an abundance of available habitats for plants. There was also a range of different habitats which promoted a diversity of vegetation types and a richness of species. The extended period of the drought meant that some of the slower-colonising plants had time to recruit and grow.

Figure 8. Some of the extremely rich vegetation that was able to colonise exposed habitats around the lake margin.

The succulent salt marsh is a pioneer community that colonised exposed lake-bed sites very rapidly and large patches were able to form at times; especially along the western margins of the lake. This community dies very rapidly if inundated (Figure 9). The more persistent *Juncus kraussii* (incema) also grows in salt marsh conditions. It can also grow in fresh damp areas. Along the lake margins it required a period of a few years without lake inundation to colonise. Where it has colonised it now is growing as an emergent species along the flooded lake margins where it can withstand flooding by low salinity water (Figure 10).

The groundwater seeps were a feature of large areas of the eastern shoreline during the drought. They were colonised by groundwater-dependent plant communities. In places this formed a margin to the exposed lake bed that was over 100 m wide. Where there was fresh or low-salinity water reeds thrived during the drought. A particularly lush fringing margin of reeds developed in the Narrows. Reeds also formed in places where there was freshwater seepage. Reeds in localities where there was no freshwater supplementation (such as on Fanies Island) often showed drought responses by browning off and dying. Saline grass lawns survived on the margins. Where there was some dampness these were dominated by *Paspalum vaginatum*. When flooded by a lake level rise they quickly lost their submerged leaves, but the above water component still continued growing.

Submerged macrophytes have the capability to respond rapidly to salinity changes. Early in the drought *Zostera capensis* was exposed by low lake water levels. It is not known if it has been able to survive in the system. The most abundant submerged macrophyte has been *Stuckenia pectinata.* It thrived in the low salinity conditions in the Narrows – where it had not been recorded prior to this drought. At times it was very abundant in Makakatana Bay and in the Brodies Shallows. Both *Ruppia cirrhosa* and *S. pectinata* have grown in South Lake whenever salinity levels have been suitable.

The mangroves in the Narrows have survived the low water level conditions. As the water was not tidal, the mud under the mangroves became hard and dry. There was no successful growth of mangrove seeds so there has been no recruitment. Browsing by kudus killed smaller mangrove trees in places (especially *Bruguiera gymnorrhiza*) and formed a browse line in places at about 2.2 m – the height a kudu can reach. The mangrove areas were colonised for the full drought period by the snails *Cerithidea decollata* and the large *Neosarmatium africanum* crabs, but the fiddler crabs (*Uca* spp.) which have a marine phase in their reproduction, were absent.

Figure 9. Salt marsh growing on the remnants of an algal mat at Makakatana.

Figure 10. Emergent vegetation in the Brodies Shallows area.

During the drought we gained a lot of knowledge about groundwater seepage along the lake shorelines and how this created groundwater-dependent habitats. The shorelines where the most seepage occurs were mapped and correlate with the groundwater models which provide some prediction of seepage water quantities. A species-rich vegetation developed on these shorelines when lake level dropped. Now that lake level has risen this vegetation forms a band of emergent vegetation along the shoreline.

The high water levels and intrusion of salt water in 2007 killed some of the trees growing in the Lower Mfolozi swamp. The main trees killed were *Bridelia micrantha*.

The drought created opportunities for invasion by alien plant species. These include the woody Brazilian pepper shrub, *Schinus terebinthifolius,* which is colonising mangrove areas. It can tolerate some salinity and is a problem in mangrove areas in other parts of the world. Another woody shrub is the salt cedar, *Tamarix ramosissima*. This plant is being carried down the rivers and has formed dense thickets on the banks of the lower parts of the Mfolozi River. It has now spread into the Narrows as far north as the Brodies Shallows. It also can thrive in saline soils and has the potential to line the banks of the Narrows.

Along the shoreline of False Bay, and to a lesser extent on other lake shorelines, the deposits of wind-blown dust created a vacant habitat that has been exploited by *Flaveria bidentis.* This is a woody perennial that grows in very dense stands that can be more than 2 m in height. It may be that it grows in such density only when growing as an early pioneer and hence is only a problem during drought conditions.

The freshwater seeps along the shoreline of Dead Tree Bay were colonised by the floating *Azolla* sp. fern. It is likely that this was the alien species of this fern not the indigenous one as it was very abundant and robust.

4.6 Bivalves

Bivalves as a group are difficult to sample as they are widely dispersed and most benthic work is done using a relatively small grab to obtain samples. The exposure of the lake bed resulted in many bivalves being killed through exposure. It was interesting to see the large numbers of some of the species. Predominant amongst these were the large, thick-shelled *Meretrix morphina* – that had only been recorded in St Lucia for the first time in 2000. There were also patches where the stick-bait, *Solen cylindraceus* were very abundant. This species is fast growing, and has a wide salinity tolerance range. At times this species became very abundant – and was preyed on, *inter alia*, by flamingoes and grunters.

4.7 Responses of fish

With the mouth closed, those fish that have an obligate part of their life in the sea could no longer recruit into St Lucia. As a result the large schools of mullet died out, as did many other species. The gap left by these fish was exploited by Tilapia (*Oreochromis mossambicus*). We had not anticipated the abundance of Tilapia under hypersaline conditions. It was known that they are able to cope with very high salinity – but that their population should grow so rapidly, and that they should dominate the fish fauna to such a large degree was unforeseen.

Figure 11. Large schools of mullet and other marine spawners were lost from St Lucia during the drought. With the mouth being closed they have been replaced by Tilapia. (Photographer and date unknown).

There was little understanding of the possible responses of the fish populations. We knew that there would be no recruitment while the mouth was closed – this is why the 1994 Mouth management guideline document limited the period of mouth closure to 18 months. We knew that there would be die-offs of fish as the individual species reached their tolerance limits. Mass die-offs of fish were recorded whenever possible, but large parts of the system are difficult to access and so many die-off events would have been missed. Also in many cases the dying of fish would have been a slow extended process rather than a sudden event.

There were sudden events – usually during conditions where the fish were subjected to osmotic stress and then 'pushed over the edge' by warm and windy conditions. It seems as if the wind stirred up sediments, increasing the oxygen demand, and at the same time the warm water holds less oxygen. With the large Tilapia die-off the cause of death is likely to have been very cold conditions – which affected the lake more because of the smaller volume of water cooling more rapidly.

4.8 Birds populations in St Lucia

Figure 12. The shallow water and large populations of stickbait (*Solen cylindraceus*) benefitted flamingoes. In July 2012 there were 18000 Greater Flamingoes counted in Lake St Lucia.

The birds were affected differently at the different stages of the drought. First there was a 'dry-down' stage when there was a lot of food available – and at the same time wetlands in the region were drying up. The response is that birds from the region concentrated in St Lucia for the abundance of food and availability of habitats. Then there was the hypersaline phase before the lake had settled – a time of little food and few birds. Within the lake there was a range of habitats – and at times the birds would concentrate in the Narrows which were fresher (and more stable) than the rest of the system.

As the system settled into a hypersaline stage, some components of the bird fauna increased to a great extent. Pelicans exploited fish; greater flamingoes had extensive shallow habitat available – where they could reach the bottom to feed on the abundant stickbait and other components of the benthos (fauna and flora). During summer the wide beaches and exposed mud flats created good habitat for Palaearctic waders. At times shallow water supported large numbers of avocet and stilt. Over 40 000 birds were counted in the system in 2012 before the drought broke. This is the most since the counts started in 1976.

One species that was badly affected by drought was the fish eagle. These birds are territorial and if a territory was no longer able to support a pair of fish eagles the birds moved away or died. This territoriality makes the fish eagles very inflexible to change.

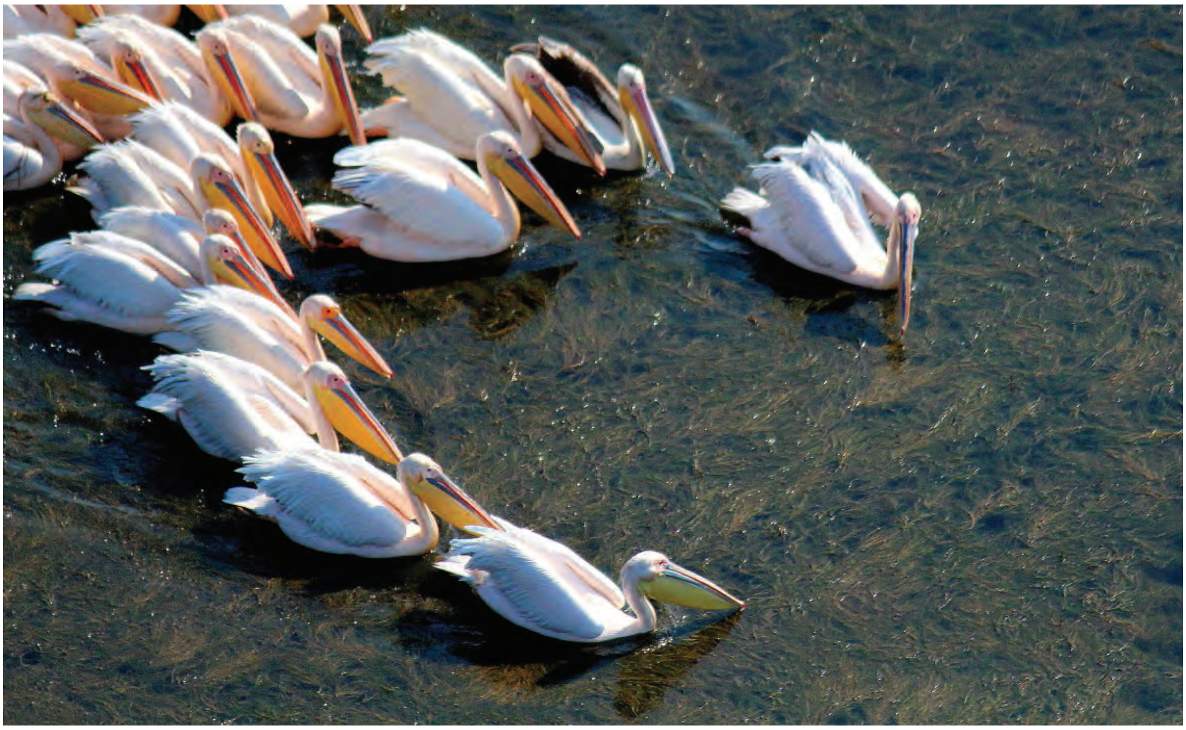

Figure 13. Pelicans feeding in a bed of *Stuckenia pectinata* at Makakatana Bay.

The Great White Pelicans thrived in the latter years of the drought. The huge population of Tilapia was of benefit to the pelicans which were able to exploit them. At one stage we estimated that there were 7000 pelicans in the system feeding on an estimated 15 tonnes of

Tilapia per day. It also seems as if the decrease in water volume concentrated the fish to high densities. The large numbers of Tilapia provided the food for the pelicans to be able to breed. The breeding event in winter 2011, when it was estimated that 2500 pelican chicks fledged, was the largest in St Lucia for decades.

4.9 Impacts of drought on hippos

Figure 14. Aerial photograph of a group of hippos in the Narrows. The concentration of hippos into small water areas caused them to aggregate into much larger herds than usual.

The hippos responded to drought by moving into the lake as the Eastern Shores pans dried up. Then as the lake levels lowered and parts dried up, the hippos moved into various refugia.

In the North Lake about 100 hippos concentrated in the groundwater-fed wallow in the lake bed east of Sengwane. Then as this also dried up, and due to the shortage of freshwater for drinking, the hippos shifted southwards. The little bay at Tewate is an important groundwater input site. At its peak over 300 hippos concentrated here – in an area of a few hectares. The hippos must have been under a considerable amount of social stress – but there was surprisingly little aggression. About a third of the total St Lucia hippo population was concentrated here at the peak of the drought – these were all the hippos from North Lake and the northern Eastern Shores.

In South Lake hippos were able to survive in Catalina Bay which had relatively deep water – and a few elsewhere. Drinking water was available from the groundwater seeps along much of the shoreline from Brodies Crossing to Fanies Island. There was also a concentration of hippos in Bhangazi – but fewer than expected – possibly due to grazing limitations. Many hippos concentrated in the Narrows – and some moved into the mouth region – which not being tidal was suitable for them. These latter hippos would graze in the town of St Lucia and drink from fish ponds, bird baths and swimming pools. During the droughts, rich grazing lawns formed in the pan bottoms, making a lot more grazing available than when these pans are full.

4.10 Crocodiles

The crocodiles seem to have survived adequately. They concentrated in the same places as the hippos – and also up the Nkazama stream and in seepage areas along the Dead Tree Bay shoreline. Breeding was reduced possibly due to less available food. One management action taken was to release captive-bred hatchling crocodiles into St Lucia. This was done to compensate for the reduced breeding that had occurred during the drought period. The nest surveys showed a severe drought-induced decline in croc nests and it was considered that by introducing captive-bred crocodiles (of St Lucia genetic stock) it would prevent a cohort gap in the population. This created the opportunity to track the movements and survival of the croc hatchlings by marking each individual.

Figure 15. A concentration of crocodiles in the Narrows.

4.11 Nutrients and features related to nutrient enrichment

During the drought period there were several perturbing signs of algal blooms that could be the first indicators of nutrient enrichment problems of the future. The incidents of concern were:

In areas adjacent to the estuarine system there was hyper-eutrophication in the St Lucia Town sewerage works. At one stage a number of waterfowl died there. Suspecting botulism, samples were sent for analysis but there were no conclusive results. Botulism, if it occurs, can spread within an ecosystem and cause large-scale mortalities of waterbirds.

An algal scum developed on lake Bhangazi-south. This was sent for identification and proved to be the blue-green alga *Microcystis*. What was not determined was whether this was the form of *Microcystis* that causes microcystis toxicity. It is a concern as Lake Bhangazi is used as a back-up water supply for Cape Vidal and microcystis toxicity could have drastic effects.

On several occasions considerable quantities of filamentous algae have been recorded from the Mkhuze River during periods of low flow. One area that was prone to this is immediately downstream of the Ophansi Bridge. This is an indicator of nutrient enrichment.

In 2007 a very wide-spread and persistent orange bloom occurred in North Lake. This was due to a cyanobacterium. The bloom dynamics were described by Muir and Perissinotto (2011).

In October 2011, during a period when the Mfolozi Mouth was closed and there was little circulation in the Msunduzi River, the water near CotCane was a verdant green colour – indicating significant nutrient enrichment from agricultural runoff.

4.12 New species in St Lucia

During the extreme conditions experienced several species new to science were discovered. This leads to the question of where the hypersaline species survive when conditions are fresh. On a similar note, has the system lost any species by being exposed to such extreme drought conditions? Where do these species survive and how important are the groundwater seeps, the fresh conditions in the Narrows and the connectivity to the Mfolozi Estuary as sources for the survival of the species that live in low-salinity water?

Much of the estuarine life is dependent on having a marine phase. These species need the connectivity with the sea. Without it larval forms cannot enter the estuary. This was noticeable for species such as the fiddler crabs, prawns, and many of the fish. We did also learn that a lot of recruitment can occur via a very constricted link – such as via the Back Channel during high spring tides when the Mfolozi Mouth is open.

There are warning signs that the St Lucia system could be subjected to alien invasive animals. During the drought period the gastropod *Tarebia granifera* was first found in St Lucia and identified as a potential problem species. There are many more species that could pose a threat – especially amongst the benthos and zooplankton. The other concern is that of diseases which could be associated with nutrient enrichment and pollution.

5 CONCLUSIONS AND RECOMMENDATIONS

The 34 Mouth Management Committee Meetings held during the 2001-2012 drought period, the informal reports generated by the management agencies at St Lucia and other materials have been used to track the events as they occurred, provide a record of the drought and the management that was implemented. Near the end of the drought the objectives guiding the management interventions changed. The management implemented must be viewed in the context of the management objectives that were accepted at the time.

The fundamental objective that has changed is that there is a switch to emphasise the importance of getting Mfolozi water into St Lucia whereas at the start of the drought the mandate was to prevent the influx of Mfolozi sediments. It is now up to the GEF funded programme to develop the necessary conceptual understanding that will support future management actions – and to interpret these to the managers. We need conceptual models of the sediment processes and how these are linked to management interventions.

It is important that future interventions are well recorded. The records should explain the objectives of the interventions and the science underpinning these objectives. The records should also detail the decisions taken and the management implemented, the responses to the management. It is also important to regularly discuss the lessons learnt.

Figure 16. Rough seas coming into the newly-breached St Lucia Mouth on a particularly high tide.(19 March 2007, R. Taylor).

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Appendix 1

St Lucia 2001 to 2012: A Decade of Drought

Sources of data and information

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LIST OF FIGURES

1 INTRODUCTION AND OBJECTIVES

The St Lucia estuarine system was severely affected by drought condition from 2001 to 2012. This appendix describes the data and materials that have been collected for the project “St Lucia 2001 to 2012: A Decade of Drought”. It describes their sources and where they are stored. This document then provides a description and the statistics for the various types of materials accessed.

The materials cover the full St Lucia estuarine system and anything that pertains to its functioning. The time considered covers the full drought period.

The drought had a very clear and rapid onset. December 2000 had good rains followed by a dry January 2001. This was a clear start of the drought as the months that followed were drier than average. Likewise the end was also very distinct. From 3 to 7 September 2012 very good and widespread rains fell, and the whole summer thereafter had well-above average rainfall and the rivers flowed strongly, the lake filled up and the salt concentration became diluted. It lasted for a bit more than 11 years.

The coverage is focused on the natural system, and not on the social impacts. However the management taken was within a context where aspects were influenced by public opinion.

2 RECORDS AND SOURCES OF INFORMATION ACCESSED

2.1 Newspapers

To track the public responses to the changing drought conditions at St Lucia newspaper articles were accessed.

Description	Newspaper cuttings
Sources	Most were obtained from the Ezemvelo KZN Wildlife Head Office in Pietermaritzburg. Ezemvelo contracts a 'Clipping Service' to scan a suite of daily and weekly newspapers for articles referring to the organisation and its activities. The clippings since 2001 are contained in 26 lever-arch files in the Public Relations section. Additional cuttings were accessed from a media file held at St Lucia EcoAdvice offices.
Quality and biases	The search by the 'clipping agency' is for articles relating to Ezemvelo, not St Lucia. This gives a bias. Generally newspaper articles provide a story which often contains factual errors and the bias of the reporter. The bias is towards provincial newspapers.
Quantity	About 255 cuttings
Method of storage	Newspaper articles have been copied and saved as .jpg files. Each article has written on it the newspaper of its origin as well as its date of publication.
Ownership and copyright	The files are public domain. The text is copyright to the newspaper

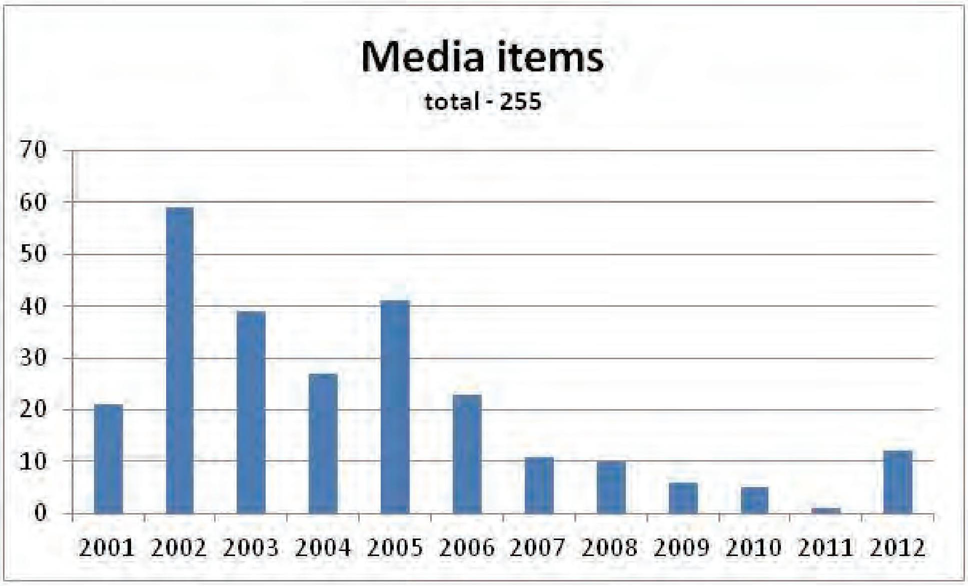

Figure 1. Newspaper coverage for each year.

A number of the newspaper articles are based on official press releases – so there is duplication in different papers. The timing of these is not random – but instigated by Ezemvelo or the iSimangaliso Authority when they put out the press release.

The clippings files accessed focus only on specified newspapers – mainly those from KwaZulu-Natal.

The accuracy of content of the articles is low.

There are also letters to the editor – which do provide insights into public sentiment.

The intensity of the clipping service changed over the years. There is not an even coverage from year to year. In addition some of the files have been misplaced.

This exercise only looked at newspapers – and not other media (TV documentaries or news items, magazine articles etc).

The bar graph of the numbers of clippings shows a decline as the drought progressed. Why is this? Is it due to a decline in media coverage or less intense collecting of clippings? Many of the earlier news items for St Lucia were coupled with other news events, such as the 4x4 ban or the stranding of the *Jolly Rubino*.

2.2 Scientific publications

Advances in scientific knowledge were tracked through formal scientific publications

Description	Formal articles published in scientific journals
Sources	Scientific journals
Quality and biases	High quality, but very focussed.
Quantity	111 publications.
Method of storage	Electronic files – usually in.pdf format. In some cases the abstract is provided. There may also be text providing an interpretation for the managers of the park
Ownership and copyright	Copyright to the publishers. Articles cannot be freely distributed

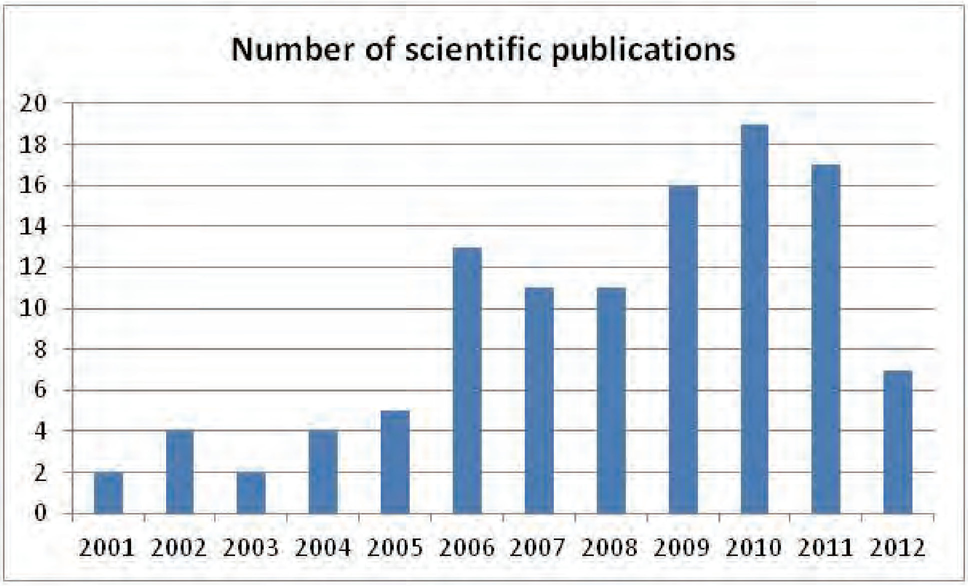

Figure 2. Scientific papers published for each year.

As the drought progressed, so did the scientific effort. As there is a lengthy lag in publication after the work has been done, the graph does not indicate what was being done at any particular time.

In addition to formal scientific publications, there is a lot of informal scientific knowledge which is gained by having scientists working in the area.

2.3 Reports

Many informal reports are produced that are not published in any way. These proved to contain a wealth of knowledge which would otherwise not have been recorded.

Description	Informal, unpublished
Sources	Ezemvelo
Quality and biases	Quality is variable, but generally no reviewing is done. The reports are written by involved officials, and so have the biases of their perspectives.
Quantity	325 reports and informal documents
Method of storage	Word documents
Ownership and copyright	Ownership belongs to the institution which produced the reports

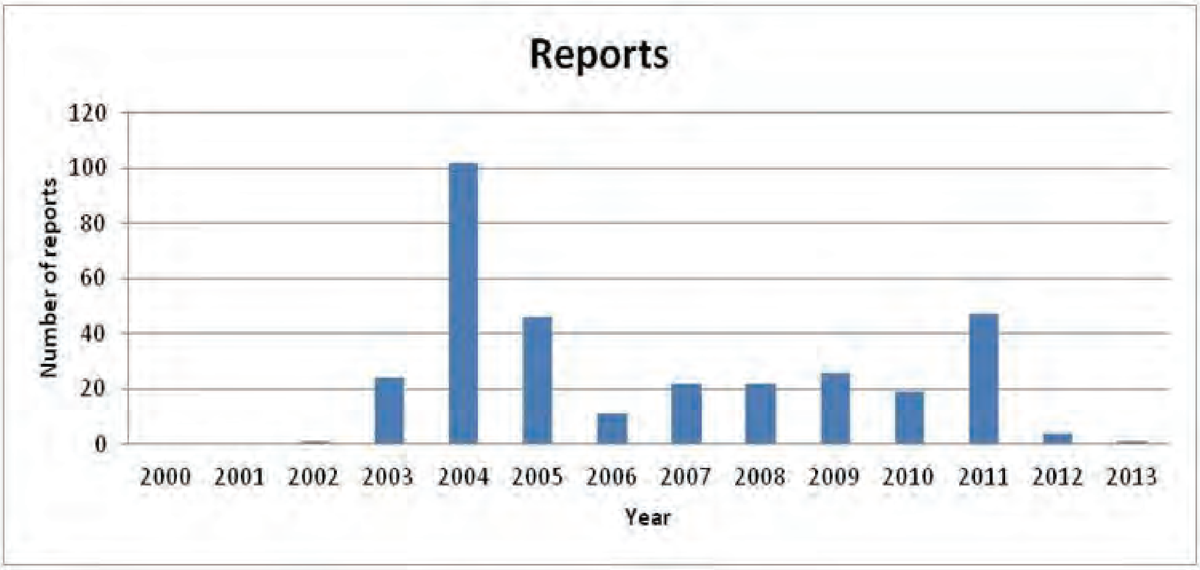

Figure 3. Unpublished reports produced for each year.

A lot of detail is captured in the monthly reports of the Ezemvelo EcoAdvice team. They contain feedback on what the EcoAdvice staff did on a month to month basis, and feedback on the state of St Lucia. These reports have changed format over the past decade.

They start in 2003 and there are several gaps – either when no reports were written or when there are missing reports. There are also many *ad hoc* reports – usually focussing on a specific issue or event. We did not access reports from other institutions.

2.4 Minutes of meetings

A number of meetings are held within Ezemvelo which discuss the state of St Lucia, management actions and other issues of concern or interest. Minutes are kept of all these meetings and they contain varying amounts of information. The most important of these meetings are the Mouth Management Meetings chaired by the Conservation Manager for the iSimangaliso Wetland Park. Many of these meetings contain support documents and are accompanied with presentations.

Description	Minutes of formal meetings to discuss management issues. The main meetings of relevance those of the Mouth Management Committee
Sources	Ezemvelo
Quality and biases	Minutes summarise what was discussed at a meeting and hence do not provide much detail. The focus is specific to subjects covered by the agenda of that meeting that of the meeting
Quantity	There have been 34 Mouth Management Committee meetings in the drought period.
Method of storage	Word files
Ownership and copyright	Ezemvelo

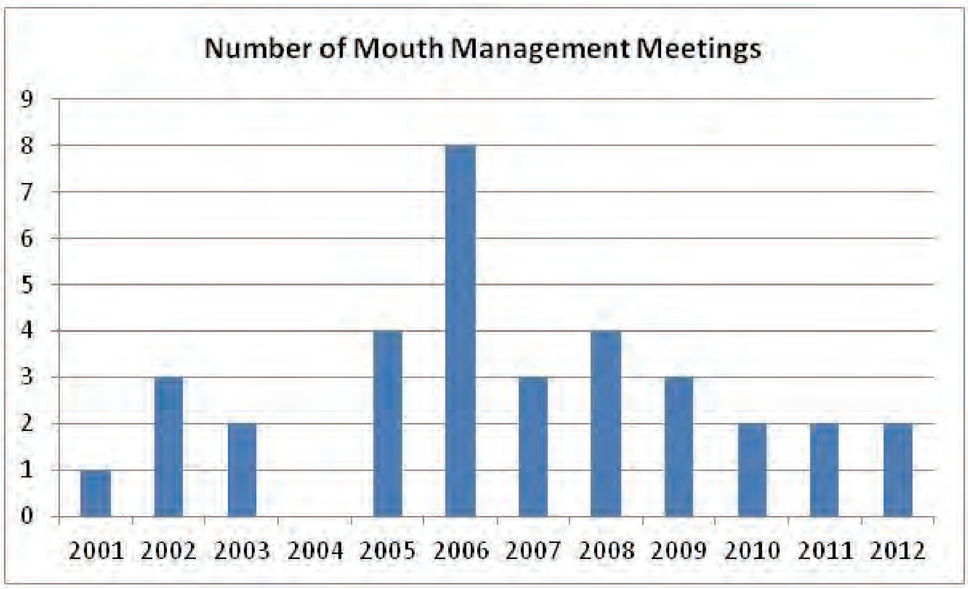

Figure 4. Minutes of the Mouth Management Meetings produced for each year.

Other minutes with relevant information on the progression of the drought include the Conservation Operations Committee for the Park. Often there are supplementary documents that are distributed with the agendas for the meetings. These are usually classified as *ad hoc* reports.

2.5 Presentations

Many of the presentations given at a variety of forums are done using PowerPoint, and as such provide a record of what was said. Presentations were given at internal committee meetings, meetings to inform the public, presentations at symposia and university lectures, and ones focused on specific interest groups.

Description	Formal presentations
Sources	Ezemvelo, Scientists from various institutions
Quality and biases	Usually a presentation contains ideas and concepts or descriptions, but not hard data. They often have a strong graphic nature – showing graphs, illustrations and photos.
Quantity	121 presentations
Method of storage	Usually a PowerPoint presentation (.ppt) or saved as a .pdf file
Ownership and copyright	Owned by the institution or individual giving the presentation

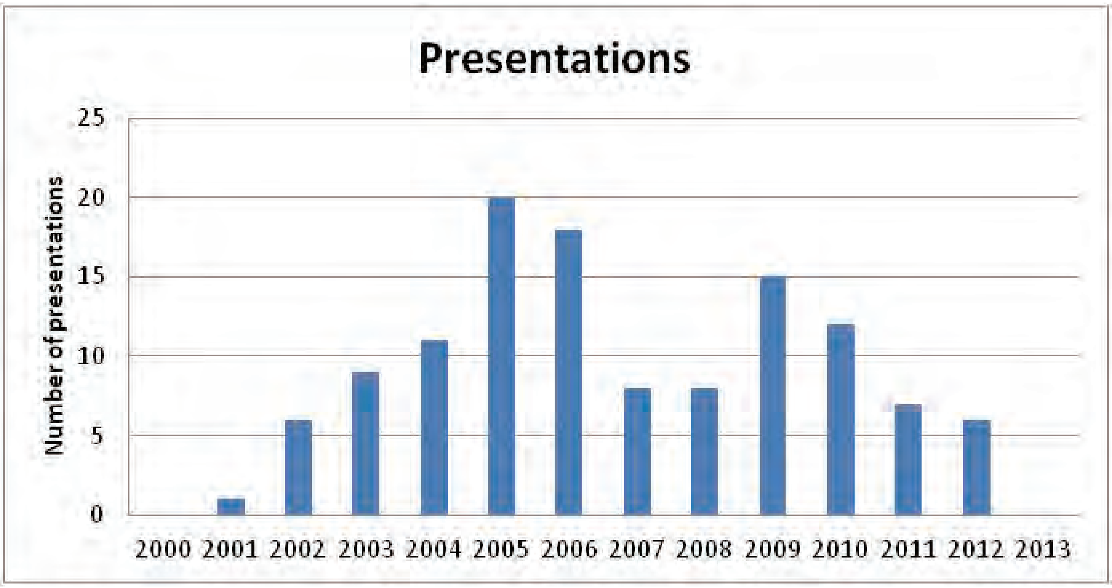

Figure 5. Power Point presentations produced for each year.

2.6 Photographs and images

With the increasing availability and use of digital imagery over the past decade a large number of photos were taken. Some 35 mm photos taken using film were scanned for the earlier years of the drought.

2.6.1 Informal casual photos

Most of the photos are informal, taken by staff and members of the public, and they cover a wide range of subjects. Each photographer sees things differently and, depending on his/her background, takes photos of different subjects of interest. These have not been collected or catalogued – but some photos have been used to provide information of conditions at specific times.

Description	Digital images
Sources	Individual people
Quality and biases	Variable
Quantity	About 10 000 were accessed, but not catalogued or stored
Method of storage	Jpg files – these generally have Exif information attached to them which provided details on date and time as well as camera make and photographer.
Ownership and copyright	The photos are stored privately by each photographer.

2.6.2 Formal fixed point photos

EcoAdvice set up formal points from which fixed-point photos are taken. This exercise started in 2006 and the photos are repeated at regular intervals. There is also scope to use informal photos to compare differences – by relocating sites when older photos have been taken and re-taking them. A difficulty with fixed-point photos is that, although change is shown very clearly qualitatively, .it is difficult to quantify changes.

Description	Pan photos taken from fixed points as part of a monitoring programme to record shoreline changes
Sources	Ezemvelo EcoAdvice at St Lucia
Quality and biases	Generally quality is high as they are in high resolution and a tripod is used to reduce fuzziness when enlarged. The photos are ‘stitched’ together to provide a panoramic view. There is loss of detail when this is done, so it is often necessary to go to the original photos to see maximum detail
Quantity	15 sites along the shorelines of St Lucia
Method of storage	Jpg files
Ownership and copyright	Ezemvelo

2.6.3 Oblique aerial photos

As Ezemvelo has its own aircraft, there is a lot of flying for various purposes over Lake St Lucia. During many of these flights informal oblique aerial photos are taken. There is also the formal monthly ‘security flight’ over the whole system and regular photos are taken of the Mkhuze Mouth and the St Lucia – Mfolozi Mouths. In addition formal photos are taken of all the estuary mouths in the province each September (since 2005). These include the St Lucia and Mfolozi mouths.

Description	Oblique aerial photos – taken from altitudes of 100 m to 3000 m
Sources	Incidental photos – taken privately while flying for other purposes Monthly photos of the Mfolozi and St Lucia Mouth area, of the Mkhuze Mouth and of items of security interest. Photos taken each September during the annual photographic survey of the estuaries of KZN
Quality and biases	Quality is variable.
Quantity	There are very large numbers of photos. More than 8 000 taken during 110 flights were recorded. They are stored by the person who took the photos.
Method of storage	Jpg files. These generally have Exif information attached to them which provided details on date and time as well as camera make and photographer
Ownership and copyright	The informal photos are in private ownership. The formal ones are stored and curated by Ezemvelo

2.6.4 Vertical imagery

There is an easy availability of imagery from a number of sources that provide satellite and aerial images. The most ubiquitous of these are the images available from Google Earth. Also freely available are the daily Modis satellite images – but these are at a coarse resolution. Ezemvelo has a lot of images archived in the cartography section at the Head Office in Pietermaritzburg. Each year since 2006 Ezemvelo has purchased high resolution SPOT satellite images with coverage of the full province. Resolutions and file formats vary between each set. There is not a consistent set from a particular source at a particular resolution for the period from 2001 to 2012.

Description	Vertical air photos from the Director General of Surveys & Mapping, Satellite imagery from Google Earth, SPOT, Modis and other sources
Sources	These are commercial products. Only the Google Earth images can be used without copyright limitations. The Ezemvelo has copies of the air photos and an annual SPOT image (since 2006).
Quality and biases	SPOT has a 5 m extrapolated pixel. Modis has a pixel of 250 m.
Quantity	-
Method of storage	Electronic files
Ownership and copyright	SPOT is not in the public domain, but licenced copies are available at Ezemvelo for use in registered projects. Modis and Google Earth are available for downloading from the internet.

2.7 Databases

A lot of information is contained in formal databases. Note that in some hydrographic databases the data are stored in the water year and not a normal calendar year. A water year is a term commonly used in hydrology to describe a time period of 12 months. It is defined as the period between October 1st of one year and September 30th of the next. The water year is designated by the calendar year in which it ends (The year within which 9 of the 12 months fall). Thus, for instance, the 2010 water year started on October 1, 2009 and ended on September 30, 2010.

Description	Electronic databases
Sources	Ezemvelo EcoAdvice files and files from other specific sources
Quality and biases	Variable – but generally good
Quantity	The main databases are listed below
Method of storage	Excel spreadsheet files
Ownership and copyright	Owned by the institution who collected the data. Permission for use of the data must be sought from the hosting institution

Long-term monitoring data available from Ezemvelo EcoAdvice and others

Data set	Spatial coverage	Temporal coverage	Comment
Salinity	Stations covering much of lake	Full period	>3000 records for the drought period. EKZNW
Water levels	St Lucia Bridge	Full period only for Bridge	The Charters and Listers Point gauges were inadequate to measure low water levels. Owned by DWA
Rainfall	There is reasonable spatial coverage	Full period	Data are collected and owned by several different organisations
Groundwater	Central Eastern Shores	Full period	Collected in about 20 boreholes. Owned by EKZNW
Mouth state	Mouth area	Full period	Informal coverage ranging from a weekly note whether Mouth is open/closed. Owned by EKZNW
Bird counts	Whole system	Twice a year – Full period	Aerial counts. Owned by EKZNW, deposited with CWAC
Bird nesting	Where it occurs	Event driven	EKZNW
Hippo counts	Annual	Annual	EKZNW
Croc counts	Whole system	Annual	EKZNW
Croc nests	Whole system	Annual	EKZNW
Fish die-offs	Anywhere in system	Event driven	EKZNW
Phys-chem data	Specific sites	3-monthly (UKZN), 6-monthly (UniZul)	From UKZN (Perissinotto) and CRUZ (Cyrus)

3 CONCLUSIONS

The quality of the information gained is very variable. With the exception of the scientific publications, there has been no peer reviewing of any of the materials consulted. Much of what is written is of an informal nature, but contains important observations and information. Many of the items extracted from the documents are in response to events and the unexpected system responses.

When accessing the materials for this study, the focus has been on those items that giving a rapid feedback and interpretation of the system and events as they occurred. This contrasts to the information that can be obtained from the long-term databases (e.g. salinity, rainfall, boreholes and censuses) which provide a more formal picture of changes in certain parameters.

It is difficult to extract information from photographs unless one has a specific focus (e.g. to record growth patterns of water plants). Although about 18000 photos and images were recorded, they were not catalogued in any way – and little use was made of them when drawing up the timeline.

Collection of archive materials is never complete. There are always gaps of material that is unavailable or still to be published. As the senior author has been associated with Ezemvelo for a long time, the bias is for materials held by Ezemvelo. Ezemvelo is an organisation that has a strong culture for keeping written records and documentation of events. However, generally the documents are not stored in a manner that facilitates easy access.

The main problems in acquiring information of this sort is to know what is available, and then to respect ownership and copyright. It is unfortunate that many people do not allow free access to materials and data in their custodianship.

Appendix 2

St Lucia 2001 to 2012: A Decade of Drought

A timeline of events and management interventions

EXECUTIVE SUMMARY

BACKGROUND AND METHODS

This document is an appendix to the project St Lucia: Decade of drought. It aims to document the progression of the drought at St Lucia and review management actions implemented. The documents and records that have been amassed that refer to the drought (Appendix 1) have been consulted and information has been extracted from them to develop a timeline of events. This is a sequential listing of the state of the system, events that were recorded, management actions taken and, where listed, the results of the management interventions. As photographs 'tell the story', many have been inserted to illustrate the conditions at St Lucia.

SUMMARY OF THE MAIN FEATURES OF THE DROUGHT IN THE SEQUENCE THAT THEY OCCURRED

Timeline for 2000 – A wet precursor to the drought
A year with well above average rainfall.
Salinity in the lake is very low throughout.
The St Lucia Mouth Management guidelines developed by the Natal Parks Board in 1994 were ratified and applied.

Timeline for 2001 – Below-average rainfall
Mfolozi linked to St Lucia.
Prawn catches high – was there already a reverse salinity gradient resulting in high catches in the Nyalazi River? Trawler catching prawns as they leave the mouth. Prawn poaching very high.
The Mfolozi and St Lucia share a common mouth – which was north of the beach car park.
Dredging to remove sediment from the sediment trap.
New dredge commissioned in September 2001.

Timeline for 2002 – The mouth closes
St Lucia Mouth closes in June-July.
The ship Jolly Rubino is stranded near Cape St Lucia, causing a pollution scare. As a result a protective berm of sand constructed on beach.
The ban on 4x4 vehicles on beach implemented.
Stuckenia pectinata (pondweed) is abundant in North Lake.

Heavy prawn poaching.

Timeline for 2003

This was to be a year when about 75% of the lake bed dried up. Very high salinity was measured.

Dry-down conditions were experienced in the first half of the year – resulting in large areas of dry lake-bed.

Timeline for 2004

Good rains at the end of January resulting in lower salinity.

Drought hits the system very hard and water levels are low.

Fish dying in March.

Timeline for 2005

Extreme salinity levels in False Bay, but still below that of seawater in Catalina Bay.

Mfolozi flood breaches into Link Canal.

Management intervention to prevent Mfolozi Mouth from joining with St Lucia.

Timeline for 2006

The alien snail *Tarebia granifera* is first recorded from the system.

Intervention to move the Mfolozi Mouth southwards.

Lake level very low.

Timeline for 2007 – the mouth breaches and then closes six months later

St Lucia Mouth breaches on 2 March 2007.

St Lucia Mouth closes on 24 August after having been open for 6 months (175 days).

Timeline for 2008

Mfolozi mouth closes – made a weak link on the beach rather than breaching the mouth which is a change in strategy.

Water flows in Back Channel as it possibly did last time Mfolozi Mouth closed.

Mfolozi River very dry – sub-surface flow at Mtubatuba.

Timeline for 2009

Huge fish die-off in July.

Algal bloom – mainly in North Lake.

Very severe salinity conditions.

Timeline for 2010

Drought continues to be very severe.

Timeline for 2011

Good rains at start of New Year.

Good catches of grunter at Charters Creek.

Dense stands of the alien plant *Flaveria bidentis* along the shoreline in False Bay.

Management strategy changes – to less intervention with Mfolozi Mouth.

Second outlet excavated for Back Channel.

Good bird breeding – Great White Pelicans, Caspian Terns and White-breasted cormorants.

Timeline for 2012 – The drought breaks

Cyclone Irina.

Good rain from September onwards – drought is broken.

Lake level rises considerably, water volume doubles, salinity all below 35 ppt by end of year.

New Beach channel excavated to link Mfolozi to St Lucia.

APPENDIX 2 – TABLE OF CONTENTS

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1 INTRODUCTION AND OBJECTIVES

1.1 Background

Lake St Lucia was affected by a drought for the period 2001 to 2012. Rainfall was low for most of this period, there was little flow in the rivers, the level of the groundwater table in the adjacent sand catchment areas dropped and Lake St Lucia was severely affected. Relatively little was recorded about the hydrological and ecological responses of Lake St Lucia during previous drought conditions. There was poor documentation of management responses and so a new generation of managers has not been able to learn about the previous drought conditions or management interventions during these periods. The purpose of this appendix is to provide a timeline that describes the progression of the drought and the management actions that were implemented.

1.2 Structure of the report

This appendix is based on the documents and records that have been amassed (Appendix 1) that refer to the drought. They have been used in the sequence of occurrence to develop a timeline of events. This is a sequential listing of the state of the system, events that were recorded, management actions taken and, where listed, the results of the management interventions.

For those enduring a drought period, there is no way of knowing how long it will last. It seems logical therefore to show what happened month by month within each year, often in the words or style of the person making the record. Generally the source of most statements is obscure. Often the primary source is lost as a statement ends up in different reports, minutes of meetings or in newspaper articles. Therefore each statement is not linked to an author. The events have been listed without opinion and what was said or documented has been reported; explanations have been provided where necessary.

2 PREVIOUS DROUGHTS

From the scientific perspective, ‘drought’ is a poorly defined term. It can be expressed in various ways by describing the amount by which rainfall has been reduced, or how the rivers or groundwater table have been affected. It can be described by how it affects people; in terms of the availability of drinking water, the growth of crops or the amount of grazing available. It can also be described by the way it affects ecosystems. However, although the word is vague, the people affected know what drought conditions are and hence the word ‘drought’, in the informal context, is used throughout this document. It is not used as a scientific term, but as one that is in common use and defined by the Oxford Dictionaries as “a prolonged period of abnormally low rainfall; a shortage of water resulting from this”.

Droughts are natural, and the species in an area are adapted to survive periodic drought conditions. That these drought conditions can be aggravated by human impacts is well understood. Excessive abstractions of water, planting of alien trees for forestry production, loss of wetlands, the diversion of rivers, the building of dams (large dams and farm dams) affect flows, and the excessive use of groundwater all aggravate the effect of drought conditions. The Zululand region is characterised by having annual rainfalls that deviate a lot from average. It is prone to periods of years where rainfall is well below average. It also has years when rainfall is well above the average. As the St Lucia Estuarine System is very shallow with a relatively large surface area it is very sensitive to these deviations from average. During dry years the rivers stop flowing and the water balance in the lake moves towards one where evaporation exceeds freshwater gains. This balance has been aggravated by human-caused reductions in the quantities of water that flow into St Lucia.

The primary responses of the St Lucia estuarine system to drought is a lowering of water levels, so much so that parts of the system can desiccate, and concentrate salt that is in the system. There are also other impacts – such as the accelerated rates of erosion in the catchments due to loss of vegetation cover. The sediments which are transported towards the sea, and the accumulation of nutrients and other pollutants are most evident during drought periods. These are the drivers of the biotic responses.

There have been previous lengthy droughts. The 13 years of drought from the early 1940s to the mid-1950s the drought from 1968 to 1972, and the shorter droughts of the early 1980s and that of 1993. Little is known about the 1940-50s drought. However, some of the management actions taken then, and the philosophy guiding drought period interventions, are still evident. These include the separation of the Mfolozi from St Lucia and the concerns about accelerated sedimentation. Dredging was initiated as a result of that drought to remove accumulated sediments and hard structures were designed to keep the mouth open. The aftermath of that drought led to the St Lucia Commission of Inquiry (Kriel, 1966) which set the basis for a scientific understanding of the hydrology of the system.

The knowledge gained during the Kriel commission was severely tested in the 1968-72 drought – and led to the extensive monitoring and the hydrological modelling of the 1970s. It was deemed important to maintain an open link between Lake St Lucia and the sea. It was a period when there was a lot of confidence that engineering solutions could counter drought impacts. The identification that it was imperative to provide additional freshwater to St Lucia led to the scheme to excavate the Mfolozi – St Lucia Link Canal. The drought acted as a catalyst for intensive research, much of which was reported on in the Charters Creek Symposium of 1976. The focus of the biological research at that time was to study the impacts of saline conditions on individual species.

Conditions during and after the 1968-72 drought were reported on in the proceedings of the Charters Creek symposium (Heydorn, 1976). There was no attempt to pull together an overview. However, we can learn from the following extracts of certain ecological response to drought and gain some understanding of why certain mindsets developed in relation to drought. In the paper on macrophyte vegetation, Ward (1976) reports that *"Phragmites australis* … is widespread and dominates the islands and much of the shoreline of the main lake. Whilst exposed parts have been killed by waters of high salinities its subterranean parts have been able to withstand such inundation for longer periods, with the result that stands have regenerated on the return of more favourable conditions. Prolonged high salinities have, on the other hand, caused the plants to die out completely."

Grindley (1976) describes zooplankton responses to high salinity. "Red water, caused by the proliferation of *Noctiluca scintillens* occurred at salinity of 42-38 ppt in August 1969. A plague of chironomid midges appeared and later myriads of spiders appeared catching them. In the Listers Point area the spiders webs became so dense that plants and branches of trees were completely smothered and killed". This is an indication of a simple food web characterised by a few 'r-selected' species. Boltt (1975) recorded a similar proliferation of a benthic species as the system recovered. Vacant habitat was available and "once salinity levels dropped at the end of the drought, the snail *Assiminea* occurred in numbers that ranged from 0 to 20 000 individuals per sample" (the area of each sample was 150 x 150 mm).

The resident engineer responsible for the Reclamation Unit noted that "during the period 1969-71 when salinities were highest, channels were excavated at the southern and northern end of the lake system, in an attempt to increase the freshwater inflow to the Lake. These channels were however not so successful…" (Blok, 1976). By 1976 a total of 10.6 million m^3 of spoil had been dredged. The focus shifted during the drought to getting freshwater into St Lucia, and 5.6 million m^3 of this quantity was dredged in the 8 years prior to 1976.

The Back Channel was excavated in 1970-71 “in an attempt to divert freshwater from the (Mfolozi) river”. The channel is 4 km long, 30 m wide and was dredged to 1.8 m deep. Both ends of the channel are subjected to strong tidal influence (when both mouths are open) so there is no head of water for the water to flow towards the estuary. “Besides under normal conditions at incoming tides the sea water is pushing the freshwater upstream of the intake point and salt water is flowing into the channel. Only during floods is there enough head available, but the channel is kept closed during the rainy season, to prevent the heavy silt laden river floods from entering the estuary” (Blok, 1976).

The drought of 1968 to 1972 left a deep impression on those who had experienced it. But it was the floods of 1984 and 1987 that made everybody realize that there is only a limited amount that managers can do to intervene to counter the extreme events that affect St Lucia. These floods scoured away the man-made structures and sediments from the mouth area (Figure 1).

Figure 1. The mouth configuration changed dramatically during the floods of 1984 and 1987. This undated photograph (probably taken shortly after 1987) shows that much of the beach had been washed away. What is very evident is the pile of dredge spoil in the centre of the photograph – a legacy of the intensive dredging of sediments that occurred after the closure of the mouth in the 1950s. Photograph source unknown.

3 SEQUENCE OF THE DROUGHT

3.1 Approach

Salinity concentration is used as a measure of the severity of drought. Figure 2 provides a timeline of the salinity for the full period under review to show which periods were most affected. For each year of the timeline the salinity graph for that year is shown in more detail. The traces for the three main basins are shown, and the year is shown in the context of the preceeding and succeeding year. For the timeline for each year events are recorded month by month. In some cases, if an event was not associated to a particular month or if it spanned several months, this is shown at the end of the timeline for that year.

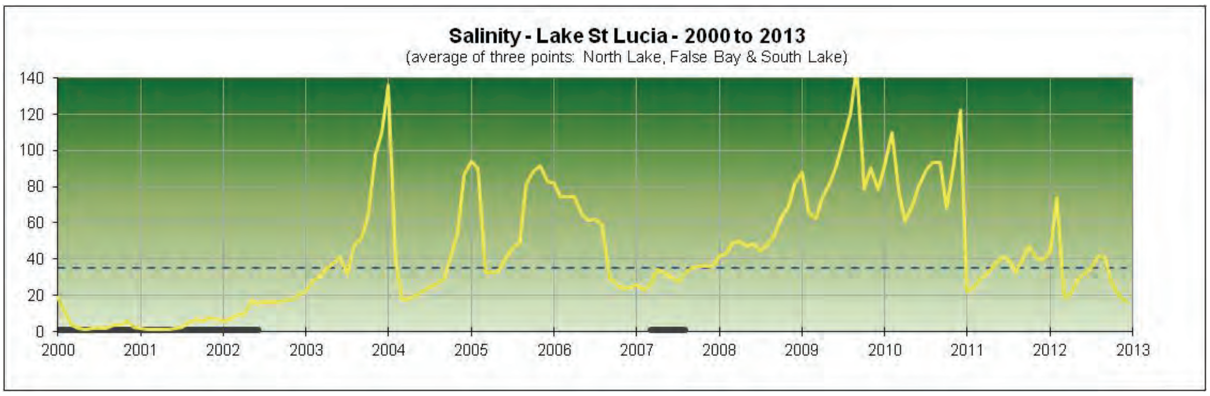

Figure 2. Graph of salinity for the duration of the drought. The black bars on the x-axis indicate periods when the mouth was fully open.

3.2 Timeline for 2000 – A wet precursor to the drought

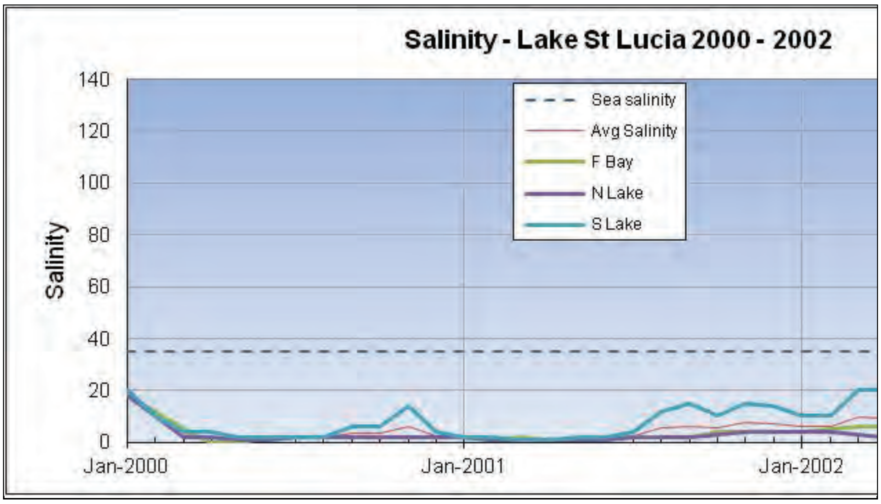

Figure 3. Salinty graph for the year preceeding the drought

Above average rainfall occurred in 2000. Throughout Lake St Lucia extreme low salinities were experienced. This was the extreme opposite swing of the pendulum compared to what was to follow.

3.3 Timeline for 2001 – Below-average rainfall

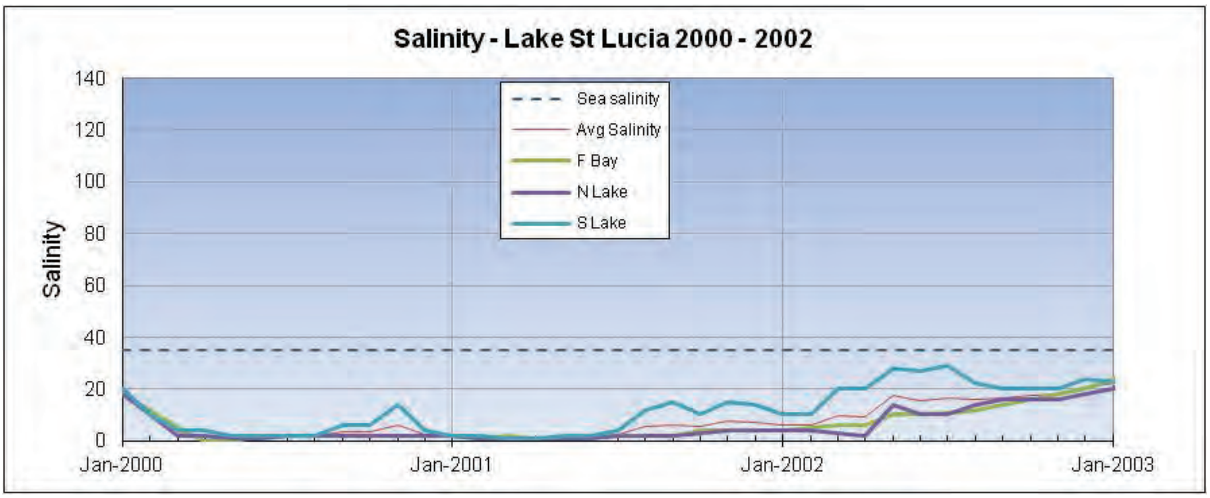

Figure 4. The salinity measurements for 2001 – the first year of the drought

January 2001

This was a particularly dry month – the start of the drought.

The trawler 'Ocean Crest' ran aground at the Mouth. There had been a similar incident in March 1999 when the 'Ocean Spume' from the same trawling company ran aground in the same place. There was a controversy about trawling so close to the mouth as they catch the immature prawns leaving the system.

April 2001

Prawns were very abundant. Anti-poaching operations caught one individual with 170 kg prawns, 200 crabs and 300 fish at Mfekai. These had been netted in St Lucia. The illegal trade in prawns is very lucrative.

May 2001

Anti-poaching officer Henry Oram was shot dead while working on a prawn case.

September 2001

The new Beaver 600 dredge was launched on 20 September 2001, costing R8 million.

The Mouth Management Committee reaffirmed the mouth management guidelines adopted by the Board of the Natal Parks Board in1994. These include:

Keeping the two mouths separate to keep out sediments;

To work with natural processes; and

Dredging of a sediment trap as the best way to control the mouth.

The St Lucia and Mfolozi mouths were linked. A decision was taken to separate them.

November 2001

The Mfolozi was linked to St Lucia and the mouth was far to the north of the beach car park (Figure 5).

The dredge was pumping sediment from sediment basin.

When planning to cut new Mfolozi Mouth Ezemvelo requested UCOSP to assist with equipment to open the mouth at Maphelane.

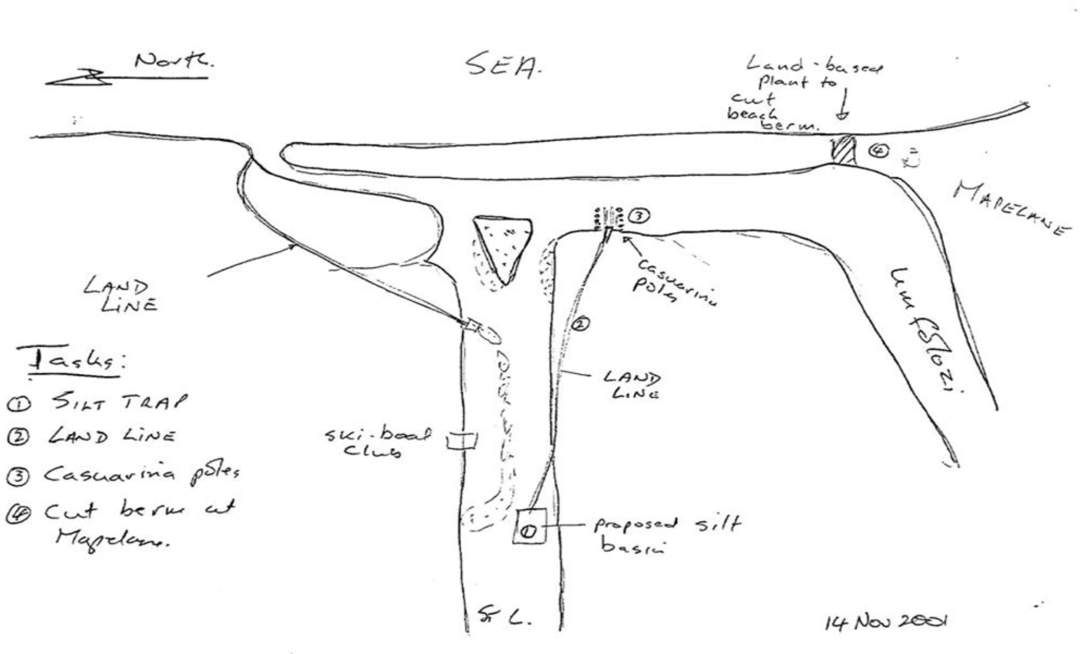

Figure 5. Sketch map showing the configuration of the mouth and the positioning of the dredge equipment in November 2001. The tasks to do are listed to the left.

December 2001

The dredge operation to separate the mouths had not been successful. A pile of spoil 300x80 m had been deposited in the channel between the St Lucia and Mfolozi Mouths, but the channel was still open.

Management

Dr Ivor van Heerden had now consolidated his ideas on how to reinstate the sediment trapping ability of the Mfolozi Swamp, these are summarised in Figure 6.

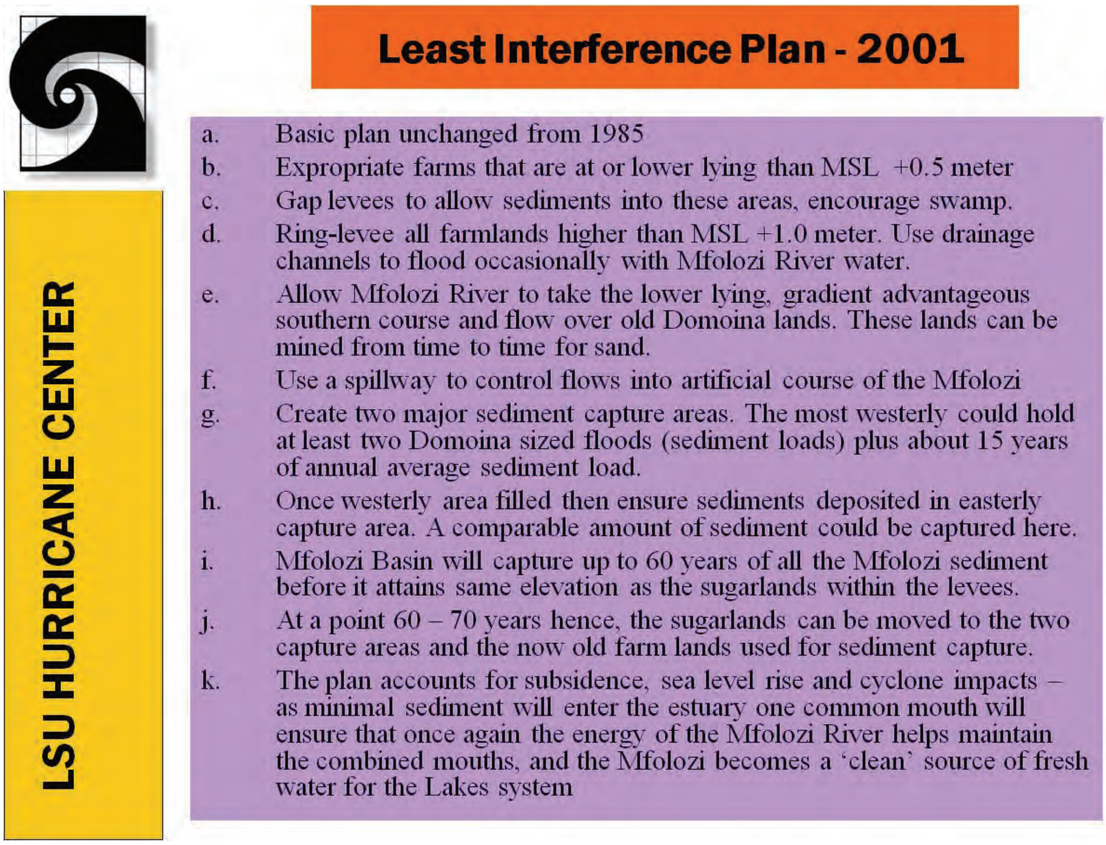

Figure 6: Guidelines provided by Ivor van Heerden for the management of the Mfolozi Floodplain so that the Mfolozi could be reconnected to St Lucia.

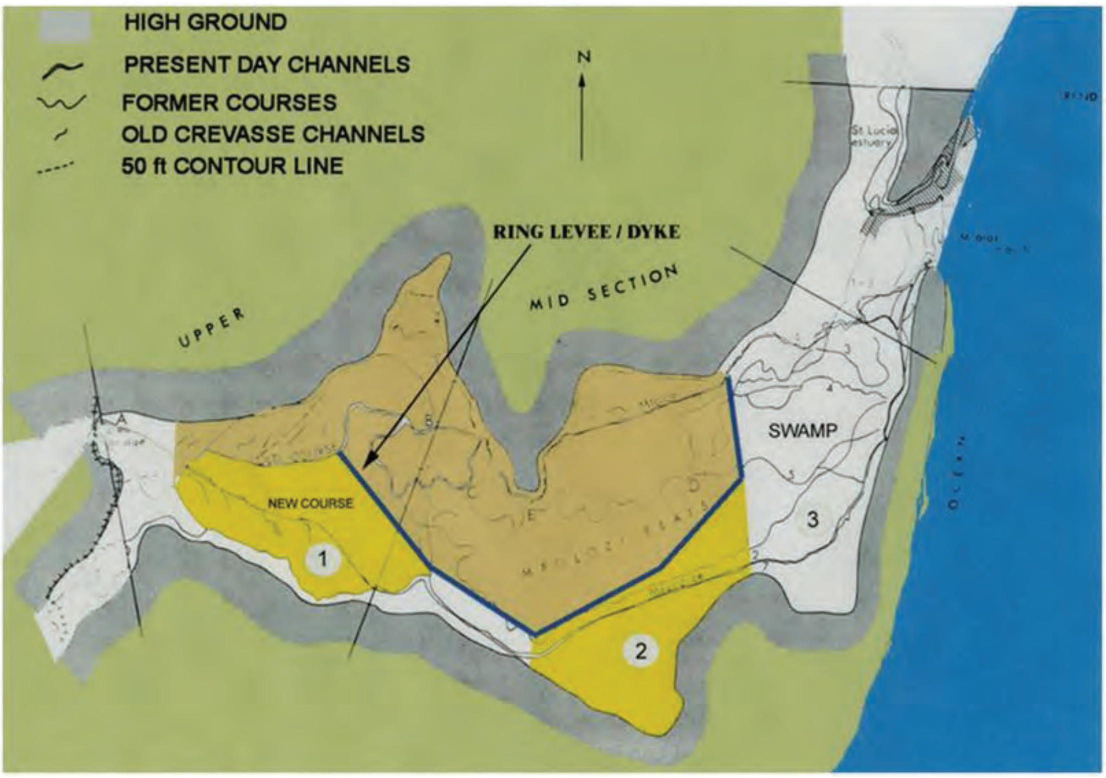

Figure 7: The Van Heerden scheme for the management of the Mfolozi Floodplain to reinstate its capacity to trap sediment. This shows the central portion of the Flats that would

be retained for sugar – which would be protected from floods with a surrounding ring levee. The floodwaters would be channeled down the Msunduzi River – as had happened naturally during the Domoina Flood. Coarse sand would be trapped in location 1. Location 2 and 3 are swamps that could be used to catch settling sediments. Natural slumping of the deep sediments would create space to accommodate incoming sediments.

3.4 Timeline for 2002 – The mouth closes

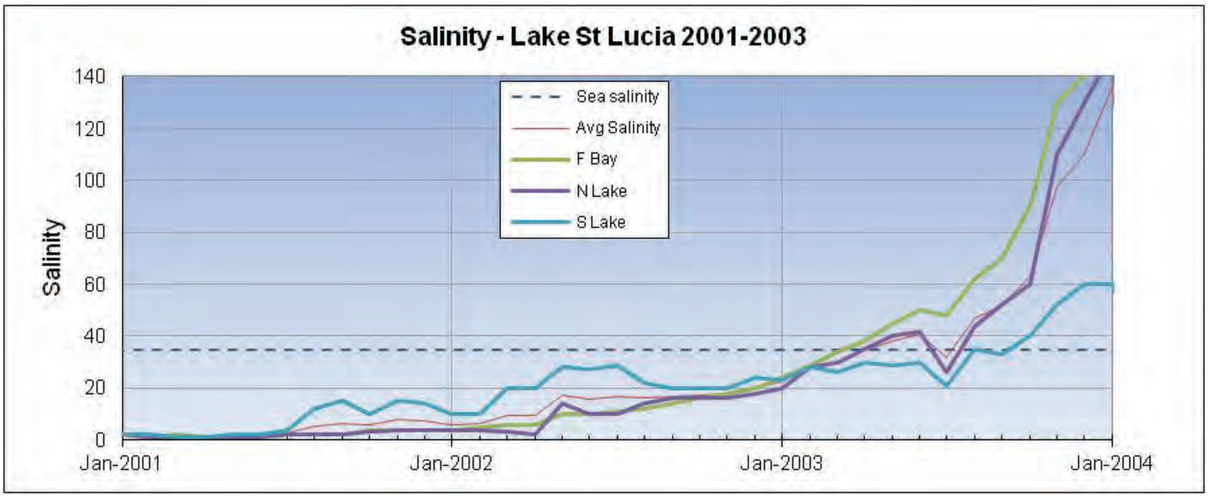

Figure 8. Salinity graph for 2002 showing that salinity was moderate – with little change after mouth closure in June 2002.

January 2002:
The planned closure of Mfolozi in December had not been successful.
The dredge pontoon sunk on south bank.
February 2002:
Poaching of prawns was abundant. The Anti-Poaching Unit caught two poachers – with 134 kg and 186 kg of prawns.
April 2002:
The Mfolozi was closed near St Lucia (after three tries) and a new mouth breached artificially near Maphelane on 19 March.
Indications were that the St Lucia mouth was close to closing.
The mouth to the St Lucia estuary was about 600 m north of the Beach Car Park.
A fisherman was taken by a crocodile at the Estuary Mouth. The previous crocodile attack was in 2000.
June 2002:
The St Lucia Mouth closed naturally. The full tidal pattern was evident on the hydrograph of the Bridge water-level recorder until 17 June. Then as the mouth was constricted, only the

high tide signature was evident on the hydrograph until the 29th. In July a tidal pattern was again evident for the period of 10 to 14 July.

At closure, lake salinity was on average about 15 ppt and water level close to that of MSL.

August 2002:

Aerial photography shows rings of *Stuckenia pectinata* in Lone Tree Point area, at Hells Gates off Observation Point 1, in the mouth of Selleys Lakes, the western shoreline of Nibela and off Rooiwalle in False Bay-north.

The pontoon that had sunk in late 2001 (on the bank opposite the Ski-boat Club) was pulled out on 28 August by an excavator and bulldozer – which had been able to get in position because the mouth was closed.

Concern was expressed about the Mfolozi River meander approaching very close to the Link Canal.

September 2002:

The ship *Jolly Rubino* was abandoned 10 September after burning. It was wrecked on beach north of Cape St Lucia on September 12th.

A 'Berlin Wall' guards St Lucia. A 2 km long wall of sand was pushed up on the beach to protect St Lucia and Mfolozi from toxic chemicals from *Jolly Rubino* if there was a spill. This occurred over the spring equinox tides.

3.5 Timeline for 2003

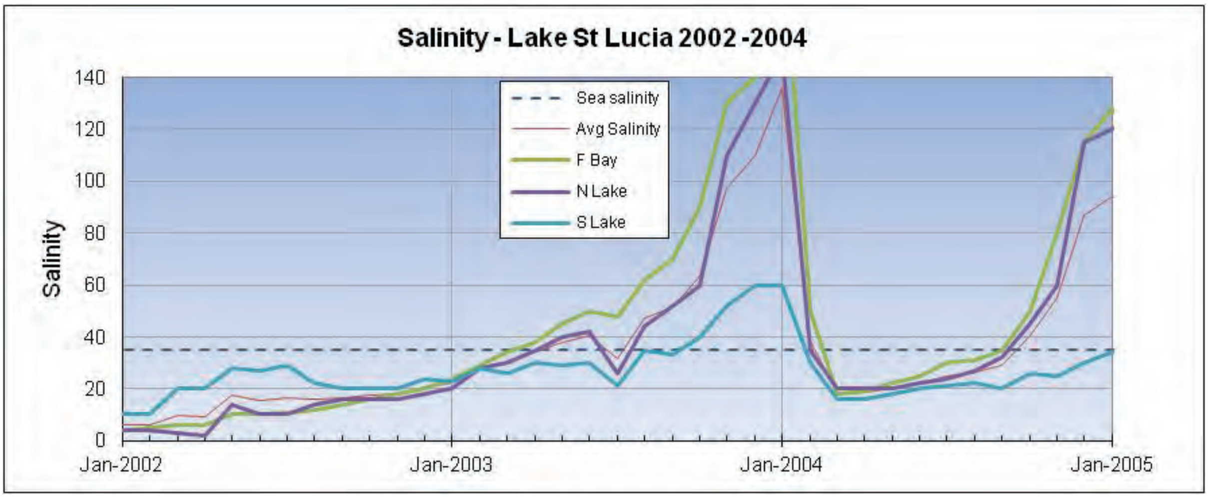

Figure 9. In 2003 salinity reached new high levels.

March 2003:

Anti-poaching staff caught a poacher with 199 kg of prawns assumed to have been netted in St Lucia.

Dredging of the sediment basin was done in preparation for when the mouth opens. There were problems with the cutter-suction dredge hitting buried dolosse. As a result the sediment basin was placed 50 m to the north. The channel being prepared for breaching was excavated to be 40 m wide.

According to the management plan the mouth must be breached within 18 months of closure. This was reassessed.

The drought in the region was severe. In the Hluhluwe Region 35 000 people were without water. Rainfall figures were the lowest in 50 years.

The submerged aquatic plant *Stuckenia pectinata* was dying off in the lake as it became too saline for it. The more salt resistant *Zostera capensis* and *Ruppia cirrhosa* were still evident south of Fanies Island. In February 2003 *Zostera* and *Ruppia* were observed in the Brodies Shallows. During the first quarter of 2003 the *Zostera* beds were exposed by the low lake levels and began desiccating and dying out.

April 2003:

It was noted that bringing in Mfolozi water had been attempted several times in previous droughts. These attempts failed for the following reasons:

1 St Lucia is a shallow estuary and cannot cope with additional sediment inputs. It was calculated that the Mfolozi-Link canal, which was scrapped in the early 1980s, would have needed an additional two dredges to remove the Mfolozi sediments brought in with the Mfolozi water. And then, these dredgers would have missed the fine sediments that would have been carried in suspension all the way into the main basins of the lake.

2 The quantity of water flowing in the Mfolozi River during a drought (such as then) was relatively small when compared to the amount of water lost to evaporation from the estuary surface.

May 2003:

Heavy prawn and fish poaching was occurring in the Lake.

Crocodiles concentrated in Tewate Bay – 185 counted photographically.

Bird Island was linked to Sengwana by a dry land connection.

Filamentous algal growth occurred in the shallow lake margins in False Bay.

Figure 10. Photograph of Catalina jetty showing exposed sand bars (23 May 2003, R Taylor).

Figure 11. Configuration of the mouths in May 2003 showing the closed St Lucia Mouth in the foreground. The dredge was excavating the sediment basin at the time, pumping the spoil northwards.

June 2003:

A train derailed in the Nyalazi catchment – 27 tankers, each containing 18000 litres of phosphoric acid overturned. Spoornet acted very quickly to prevent the acid from entering the Nyalazi River.

August 2003

Great White Pelicans breeding in the dry North-eastern Shallows. They produced about 450 chicks.

Catalina Bay was still linked to Makakatana Bay.

Figure 12. Crocodiles concentrating in the freshwater seepage area of Tewate Bay (11 August 2003, R Taylor).

September 2003:

The management authorities decided not to open the mouth until conditions return to normal.

World Parks Congress held – with a preliminary symposium at Cape Vidal.

It was stated that the drought had brought the lake to its lowest level since the 1950s.

There was almost no link between Makakatana and Catalina Bay – water flowing northwards only.

No submerged macrophytes were recorded in Makakatana Bay.

October 2003:

In an article by Bob Crass (former Head: Scientific Services, NPB) he pointed out that when the mouth is open, then South Lake is a 'low salinity' reservoir which continues to function as an estuary. He was of the opinion that the mouth should be maintained open by dredging.

The Minister of Environmental Affairs and Tourism suspended all catching of kob in the St Lucia estuary until further notice. “The recent drought conditions in KwaZulu-Natal have resulted in the significant decrease in the surface area of the St Lucia estuary. This has caused stocks of various kabeljou species to aggregate in very limited areas of the estuary. This aggregation has resulted in substantial catches of kabeljou by commercial and recreational line fishers over the past few days. These substantial catches threaten the sustainability of the kabeljou species in the estuary.”

About 100 hippos concentrated in a small puddle at the eastern end of the Sengwana peninsula. It was dry all around them.

Intensive gardening in the lower Mkhuze Swamp. This could lead to loss of swamp integrity and problems in the future.

Lane Island was linked to the Eastern Shores by dry land at Lone Tree Point.

December 2003:

The drought was ongoing and the rivers had not carried freshwater into Lake St Lucia for two years. Rainfall had been well below average. The mouth of St Lucia closed 18 months previously. Since then evaporation losses had been substantial.

Lake level had dropped to about 90 cm below sea level and large areas of the lake-bed were now exposed. The lake water surface had been reduced considerably (See Figures 14 to 17). About 75% of the lake bed was dry and exposed.

The northern parts of the Lake and False Bay were virtually completely dry.

With the low water levels and high salinities, there were no beds of submerged water plants left. However, there was a luxuriant growth of grasses and sedges in the exposed lake-bed all along the eastern shoreline – where there was freshwater seepage from the groundwater of the Eastern Shores.

With the mouth being closed there had been no fish and prawn movements between the Lake and the sea. Those prawns trapped in the lake had died out – as they have a life span of a year, and need to spawn at sea. Most estuarine fish also spawn at sea, and so there had been no recruitment of juveniles. Where salinity concentrations had exceeded twice that of seawater, fish died. Surprisingly there had been fewer fish deaths than expected.

Crocs had been displaced by the drying of pans. Most moved to the lake. Two were in the surf at Cape Vidal. (Had they been disorientated and moved in the wrong direction?).

Fish were still plentiful in the lake – but no recruitment or outward movement was possible for fish and prawns.

Large numbers of eels and nondis were seen dead along the shoreline of Makakatana Bay.

Businesses in St Lucia complained that the drought and 4x4 ban were hurting tourism. They said that there is a need to open the mouth as had been done in previous droughts.

Because of low water levels the large tour boat at Charters Creek had not operated for a year now.

Groundwater-dependent vegetation was starting to thrive in the seeps along the Eastern Shores.

Large cracks in mud off Hells Gate forming polygons with a diameter of >50 m were seen. These were clearly visible from the air in very shallow water, but we were unable to explain these.

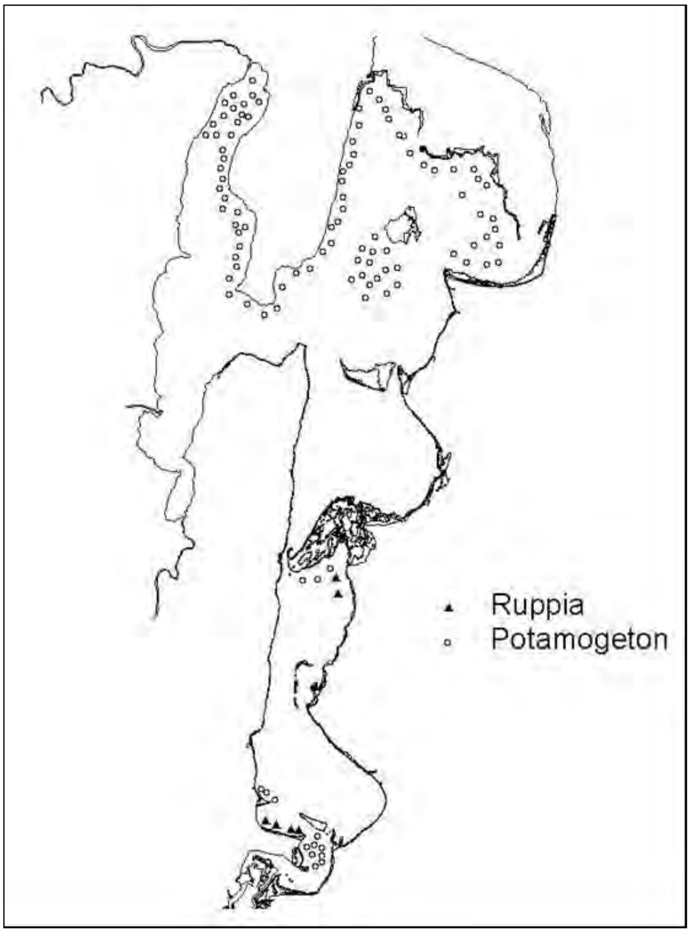

Figure 13. Distribution of submerged water plants in St Lucia, November 2003.

Figure 14. By December 2003 the water level had lowered to expose large areas of the lake bed. (Photo R Taylor).

Figure 15. The small bay at Makakatana was virtually dry. (Photo R Taylor).

Figure 16. Water remained only in the deeper parts of Tewate Bay. (Photo R Taylor).

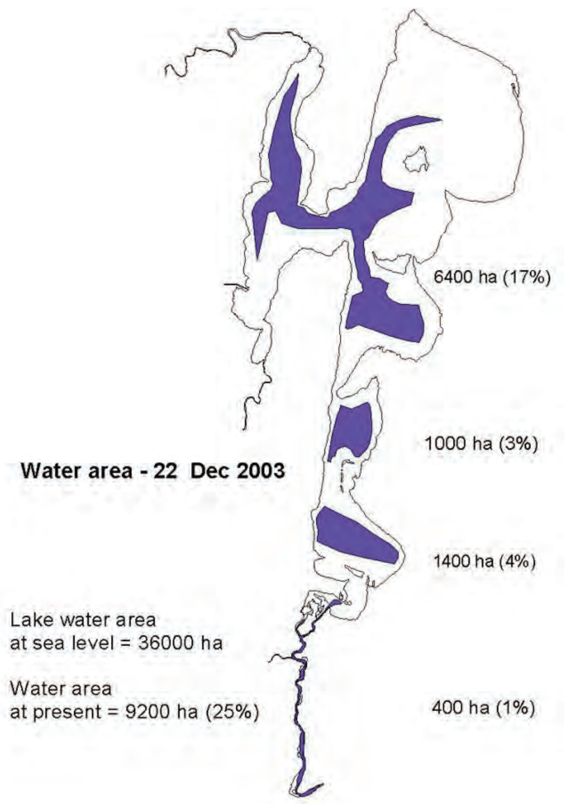

Figure 17. Map of water distribution throughout the system; 22 December 2003. About 75% of the lake was dry.

This water was in 4 basins in the lake – each was now isolated from one another (Figure 17). The Narrows (about 1% of surface area), Catalina Bay (about 4%), Dead Tree Bay (about 3%) and North Lake, False Bay (about 17%). Makakatana Bay was virtually dry – with only a very little water still present that would have been of a very high salinity.

There was a lot of shoreline seepage on the eastern shoreline south of Fanies Island to southern Brodies Shallows (see Figures 18, 19 and 20). The Nkazana Stream was flowing. North of Fanies Island freshwater was seeping into shoreline at Tewate basin and along the shoreline southwards to Fanies Island. There was very little freshwater north of this.

The extreme variability of the lake system contrasts with the extreme stability of the groundwater-dependent lake margin habitats. This seepage is so stable that peat layers have been able to form – dating back to 23 300 BP. These create micro-habitats which would act as refugia for freshwater species (Figure 21).

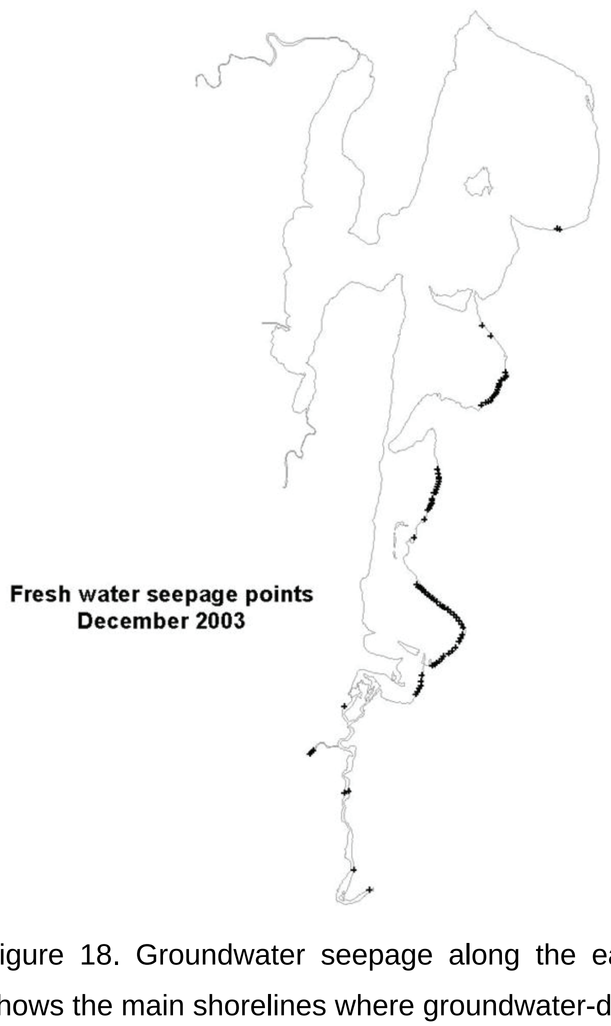

Figure 18. Groundwater seepage along the eastern shoreline was persistent. This map shows the main shorelines where groundwater-dependent habitats occur.

Figure 19. Seepage from shoreline groundwater south of Tewate Bay (27 October 2003, R Taylor).

Figure 20. Groundwater seepage on the exposed shoreline south of Old Jetty. The groundwater model indicated that such seepage would persist for the duration of an extreme drought (Photo R Taylor).

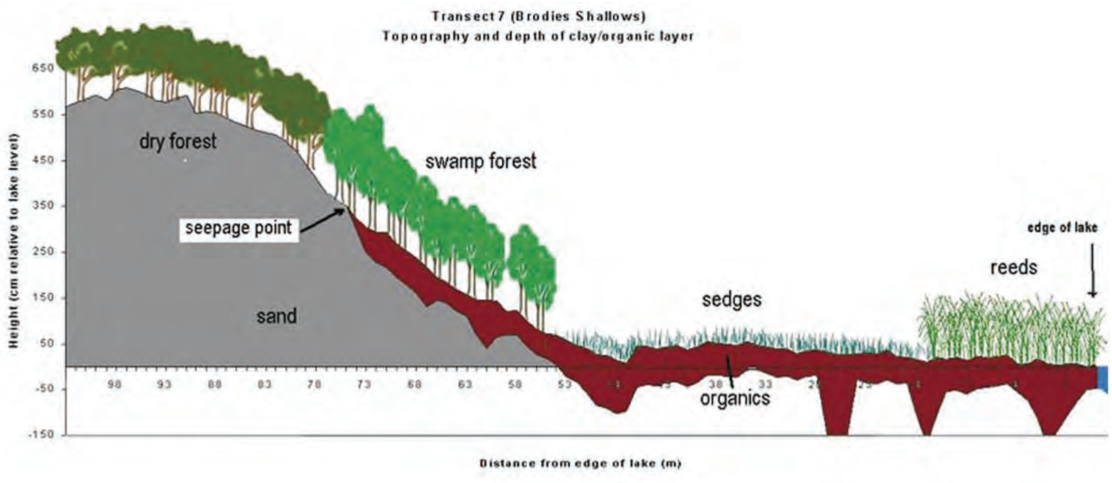

Figure 21. A schematic profile of the eastern margin of Brodies Crossing. The persistent seepage has formed peat layers that are 23000 years old. The wetlands formed by this seepage are amongst the most stable habitat in the region as theyare groundwater-fed and buffered from the variability caused by changes in rainfall patterns (Haldorsen et al, 2003).

The effects of the very high salinity in North Lake (120-140 ppt) were evident from the large numbers of dead fish seen on the north margin of Fanies Island while flying on 22 December 2003. There seemed to have been a die-off of mullet and springer although the fish could obviously not be identified from the air. There had been no mullet die-offs until now. Higher up on the same beach were dead kob – they possibly died a few weeks earlier.

In the North Lake area there were still a lot of hippos. Almost all of these were in two pods. One in Tewate Bay where there were 180-200 hippos, and one at the north-eastern margin of Sengwane – containing more than 100 hippo (Figure 22 and 23). In both cases the hippos were concentrated in mud wallows associated with freshwater seepage sites.

Figure 22. Aerial view of hippos in a mud wallow north-east of Sengwane on 27 October 2003. At this time the last remaining source of freshwater in the north-eastern reaches of the lake.

Figure 23. The Sengwana Peninsula and the dry lake bed beyond it. The wallow with the hippos shown in Figure 22 was to the far right of the photo. (22 December 2003, R Taylor).

Some salinity calculations: If the mouth had been open at this stage: The surface area of estuary would have been about 35 000 ha. The evaporation of water from this surface is about 3 mm per unit area per day. Thus 1 050 000 m^3 of water would be lost daily through evaporation from the surface of the estuary. When the mouth is open, equilibrium is reached – where inflowing seawater balances the water lost through evaporation. Thus 1 050 000 m^3 of seawater would enter the estuary daily when the estuary level is slightly below mean sea level. This seawater has a salinity of 35 ppt salt – i.e. 35 kg of salt per m^3. Thus the total mass of salt entering the system per day is 36 750 000 kg or 36 750 tons. This is equivalent to 153 ten-ton truckloads of salt being emptied into the estuary every hour.

Figure 24. Dredging of the sediment trap. Note how the dredge was eating into the beach berm. Spoil was deposited on the beach in front of the car park (22 December 2003, R Taylor).

3.6 Timeline for 2004

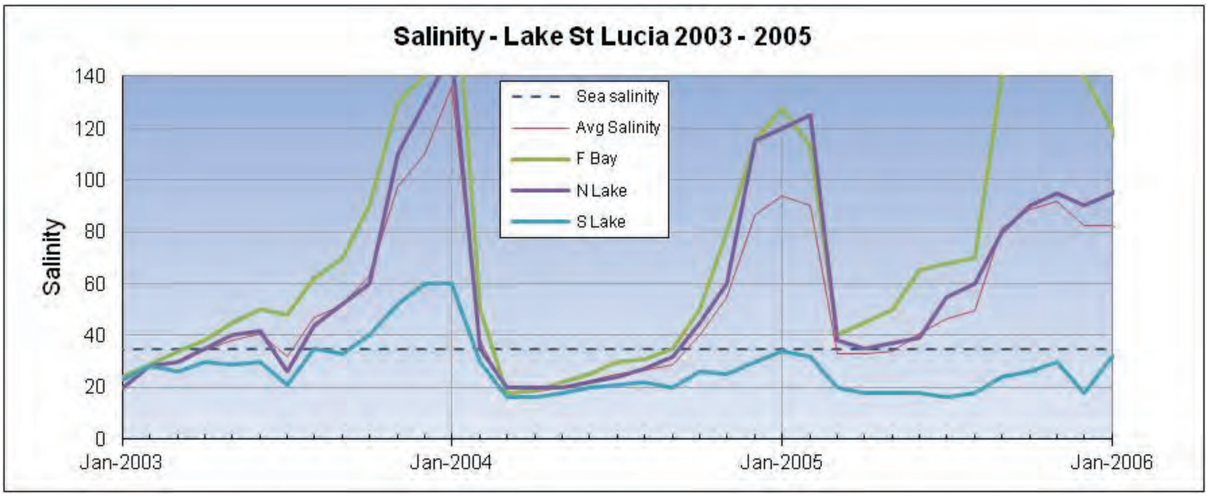

Figure 25. Salinity graph for the year 2004. This shows a high mid-summer salinity, which fell in February and then increased again after a dry winter and spring.

January 2004:

Lake level was very low – with large areas of the lake bed exposed. There were many shells of stranded bivalves (Figure 26).

Heavy rains at the end of January 2004 caused a 30 cm rise in lake level, and a lowering of salinity. Rainfall at St Lucia was 240 mm and Mantuma in Mkhuze Game Reserve had 179 mm. The lake surface increased from 20% of full coverage to 80% of full coverage in three days. In the catchment, the Hluhluwe Dam filled from 24% full to 45% full.

A significant amount of Mfolozi water entered St Lucia by overtopping into the Link Canal.

The Department of Water Affairs conducted a Rapid Water Reserve Determination. Threats to St Lucia were identified as water shortage (with the Mfolozi River being separate from St Lucia) and overfishing. (Van Niekerk, 2004)

Figure 26. Shells of the bivalve *Meretrix morphina* killed by exposure (Photo R Taylor).

March 2004:

Newspapers showed a picture of dead kob and springer. Concerned public called for St Lucia mouth to be opened to save large numbers of fish from dying. Dead kob of up to 50 kg, mullet, rock cod, eels and sting rays were found on the edge of the lake.

Joe Hansmann (Regional Director DWAF) suggested that we should re-assess whether the Mfolozi-Link canal could be used (even though it may not be used in the manner it was designed to be used).

April 2004:

Good rains caused the Hluhluwe Dam to overflow.

July 2004

About 10 days after the Mfolozi Mouth had closed it was beached artificially (On 30 July 2004). After closure there were good rains throughout the catchment. The Mfolozi backed-up behind the closed mouth to about 1.5 m above mean sea level. It was a matter of time before the water overtopped the beach berm which would then breach the mouth. With this background, the KZNW and the Wetland Authority decided to anticipate the natural breach by breaching the Mfolozi in a manner which would maximise the scouring resulting from the breach. This was done on a falling tide; a few hours before the spring low tide. The action of breaching was of benefit to the farming community in the lower areas of the lower Mfolozi Floodplain where the backing-up waters inundated the low-lying farms.

October 2004:

A field inspection was conducted by Iain Bickerton to determine if the brack-water *Macrobrachium* prawns had colonised St Lucia from the flooding Mfolozi that breached into St Lucia via the Link Canal in January. Notably, these river prawns were not recorded north of the Narrows in this survey.

In the Narrows one- to two-year old *Penaeus indicus* and *Penaeus monodon* prawns were caught – indicating recruitment since the mouth closure.

December 2004:

A fish survey by the CRUZ team showed that 45% of the fish in the system were *Oreochromis mossambicus* – a freshwater fish that can tolerate very high salinity (Figure 27). About 60% of the fish species in the St Lucia checklist were still present.

EKZNW was carting water by tanker to water points at Hells Gate for animals to drink. The groundwater on the Western Shores was so low that there was no water in the pans.

The St Lucia Lake covered about 30% of the area it covers when full. It was possible to walk across the dry lake at Fanies and Brodies Crossing.

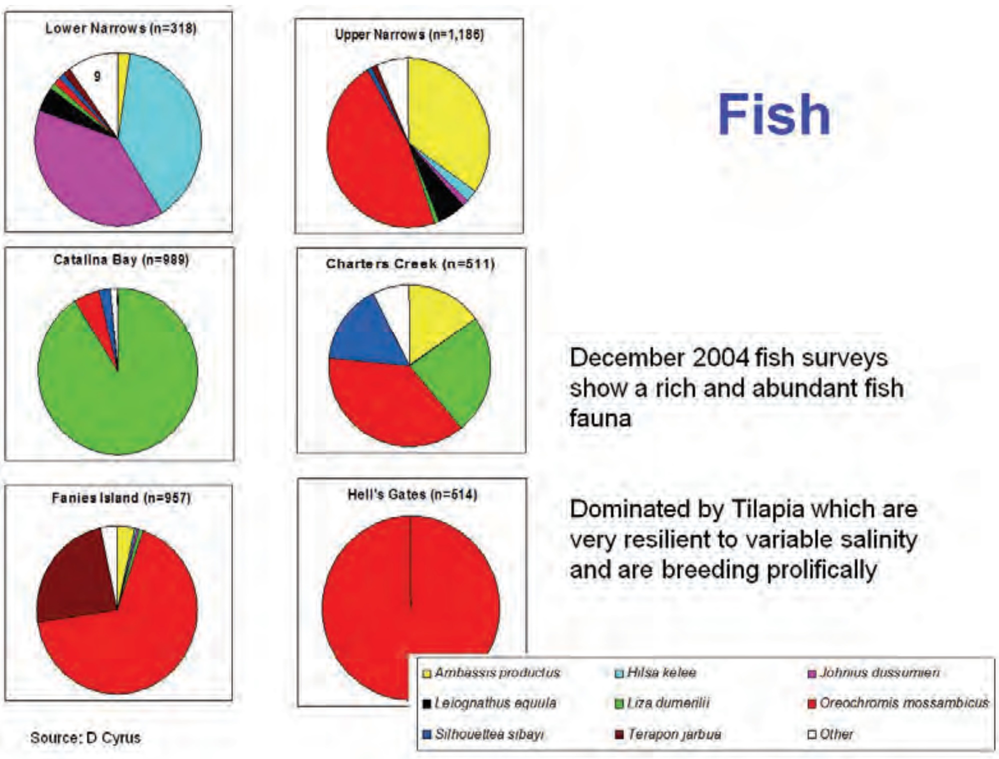

Figure 27. Fish species composition surveys in the lake, December 2004. (Source: CRUZ).

Management decisions

The Water Reserve Determination exercise completed in 2004 (as specified in Water Act) identified that it is essential to bring in sediment-free water from the Mfolozi

The EKZNW and the Wetlands Authority, jointly took the following decisions:
The mouth of St Lucia will remain closed until there is an adequate head of water so that when it is breached there is not a large influx of sediments from the sea. It could remain closed for another year or two.

2) Two options to introduce Mfolozi water into St Lucia were considered. This water will be introduced to provide relief during times of future drought. (i.e. via Link Canal or via Back Channel). A third option; that of a Beach Channel, was also discussed but discarded. (Figure 28).

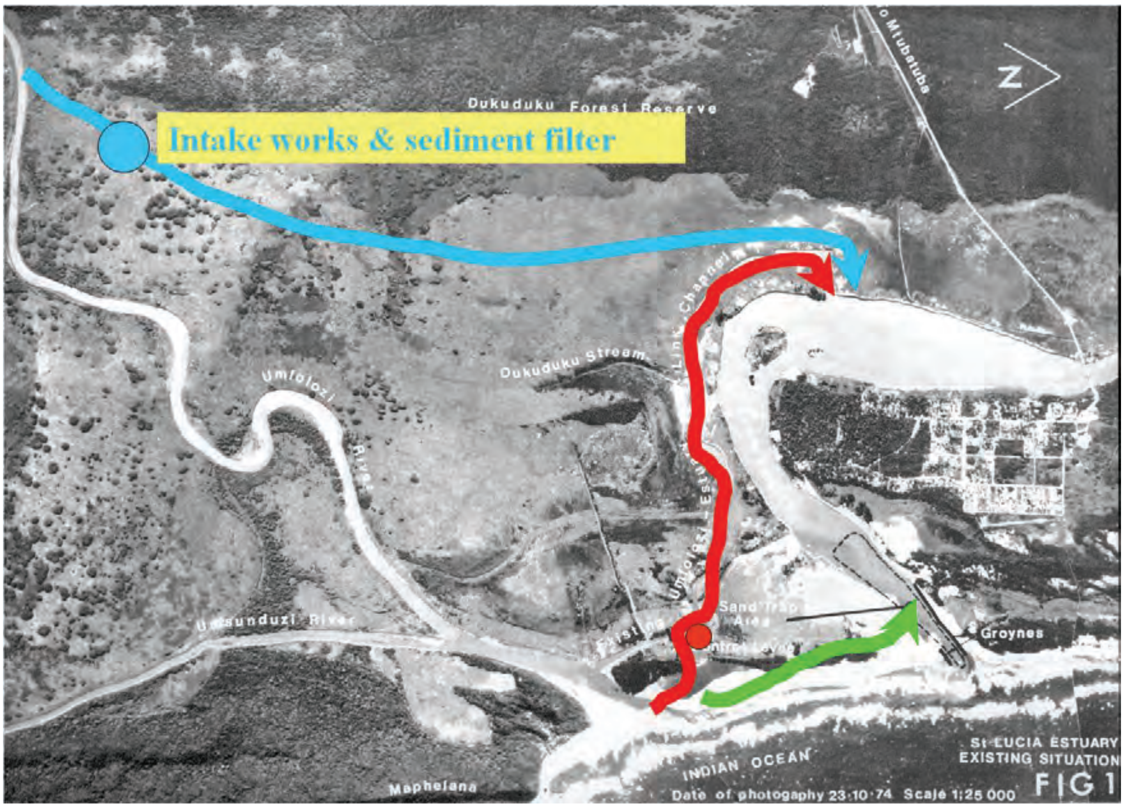

Figure 28. The three options considered in 2004 for bringing in Mfolozi water. All were rejected at the time. These were to bring in fresh water from the Mfolozi via (1) the Link Canal shown in blue; (2) the Back Channel shown in red, and (3) a Beach Channel, shown in green. The circles on the canals indicate a controlling structure.

An assessment was made as to whether the Link Canal could be used or not. The vegetation at the Intake Works was cleared, sediments deposited during the Domoina Floods removed and it was estimated that it would cost R500 000 to R750 000 to restore it. A computer simulation, by Kelbe and Taylor (2005) (Figure 33), was used to show that the amount of water available certainly would ameliorate the drought situation in St Lucia. The decision was taken to not open the canal. There were a number of reasons relating to management of the canal and anticipated side-effects.

Depths of the Mouth basin

The dredging of the sediment trap, a deep hole behind the beach berm, was to play a part in the breaching of the mouth in 2007. This had been dredged in 2003 and was surveyed in December 2004 (Figure 29)

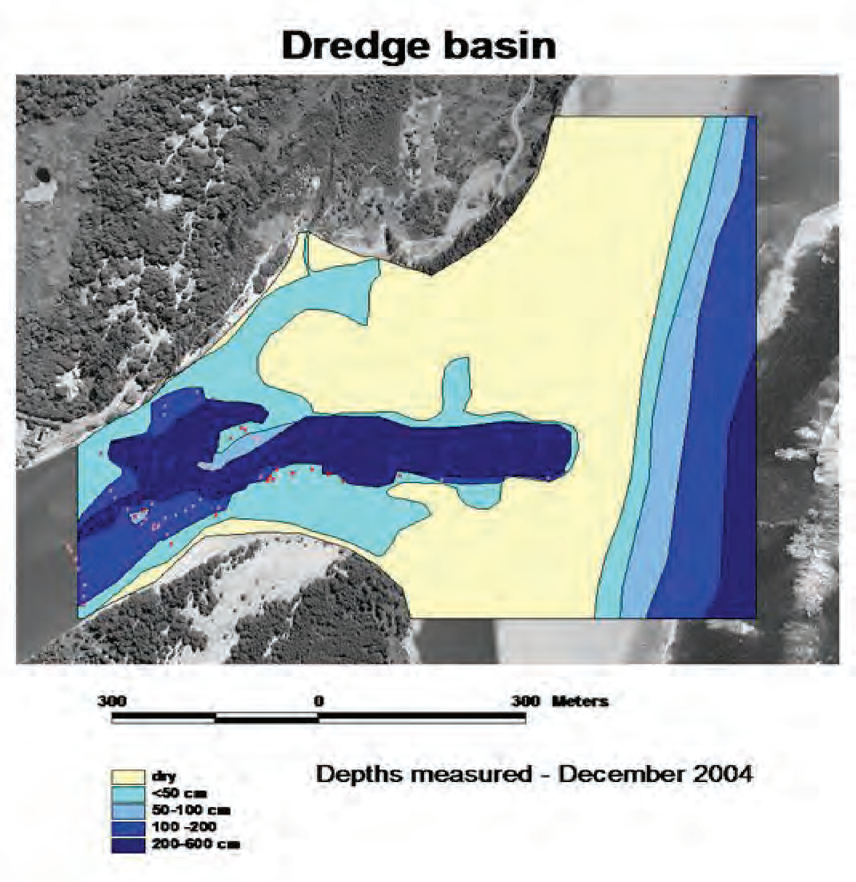

Figure 29. In preparation for breaching the sediment trap was dredged in 2003. This bathymetric survey shows the location and size of the trap.

3.7 Timeline for 2005

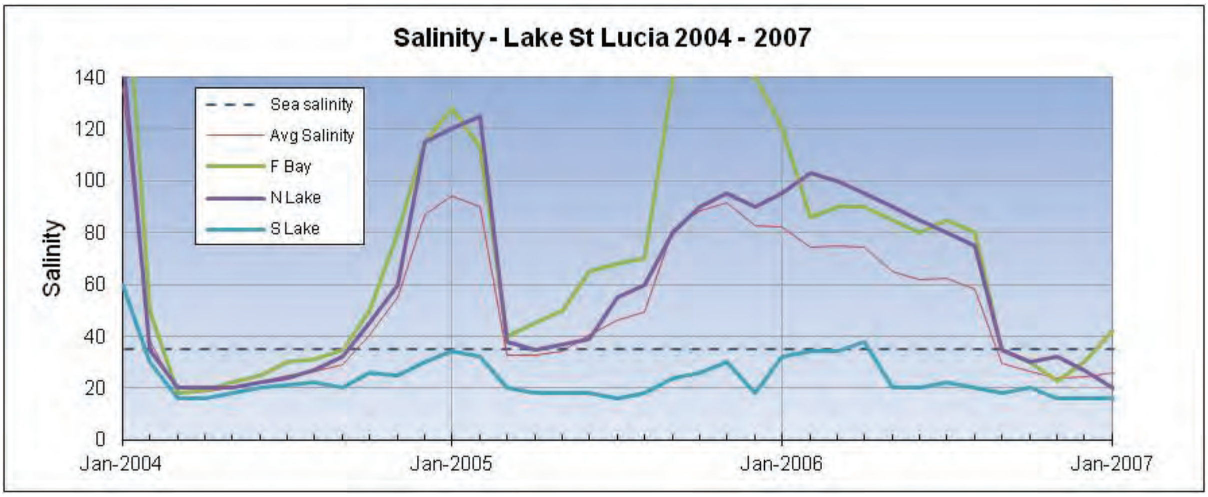

Figure 30. The salinity graph shows that the year 2005 started with high salinities. The heavy rainfall in February caused salinity to drop as the lake gained water. Then, after winter, evaporation increased and salinity again went 'through the roof'.

January 2005:

Mfolozi flood breached into the Link Canal and into St Lucia at Honeymoon Bend

February 2005:

Fishermen were at loggerheads with ecologists. The fishermen wanted to bulldoze a channel to open the mouth.

EKZNW had closed Fanies Island due to a lack of drinking water.

March 2005:

Good rains, water level rising, and all rivers flowing – but Mkhuze was still not entering the lake as it was still filling the swamp.

A crocodile killed a fisherman at St Lucia mouth. Because of the high-density tourism in the area the decision was taken to destroy the croc. At least 11 other crocodiles were in the St Lucia Mouth area at the time. There were also hippos which could be in the mouth area as they are no longer were worried by waves and tidal action.

At a Mouth Management Meeting it was decided that, when it is possible, we would have to cut a new mouth for the Mfolozi River close to Maphelane as it was shifting northwards and would cut into St Lucia if left.

July 2005:

Bird count details: 12000 flamingoes, 1500 ducks and 4000 white pelicans counted.

There were several presentations on St Lucia at the South African Marine Science Symposium held in Durban. In an important presentation P Huizinga and L van Niekerk

(2005) showed that if the mouth was to remain closed, it was necessary to increase freshwater inflow (i.e. from the Mfolozi River).

August 2005:

Built a sand wall on beach to prevent Mfolozi moving northwards and entering St Lucia

Mfolozi northwards movement from 5 June to 22 August was 2.1 m/day

Pelicans were abundant. The 5000 pelicans were eating about 15000 fish per day (mainly Tilapia).

September 2005:

Western Shores. A large forestry fire burnt much of the pine and gum plantation areas within the Mpate River catchment area. This, as well as the phasing out of the plantations in this area, reduced the transpiration losses in the area, and hence increased the stream flows.

Table 1. Quantities of water entering St Lucia with and without the Mfolozi connected to St Lucia. Note that the evaporation loss does not increase if the Mfolozi enters St Lucia – so its influence is very large. Data from Huizinga & Van Niekerk, (2005). This showed just how large an effect the Mfolozi would have if reconnected to St Lucia

Water source/loss	Quantity of water per annum (x10^6 m^3)
+ 5 rivers (Mkhuze, Nyalazi, Hluhluwe, Mzinene & Mpate)	**362**
+ Groundwater	**23**
+ Rainfall	**273**
- Evaporation	**-420**
Total annual gain (without the Umfolozi linked)	**238**
Umfolozi	**920**
Total annual gain (with the Umfolozi linked)	**1158**

October 2005:

Fish die-off at Hells Gate. Mainly *Liza dumerilii* and *Oreochromis mossambicus*. The die-off was likely to have been due to a combination of high salinity, warm water and low oxygen levels in the water.

Drought harsh. Water levels low and Lake divided into four discrete compartments.

Management

The Mfolozi Mouth was prevented from eroding into St Lucia (Figure 32).

Figure 31. A jellyfish die-off along the eastern shores of Catalina Bay. (18 December 2005, R Taylor).

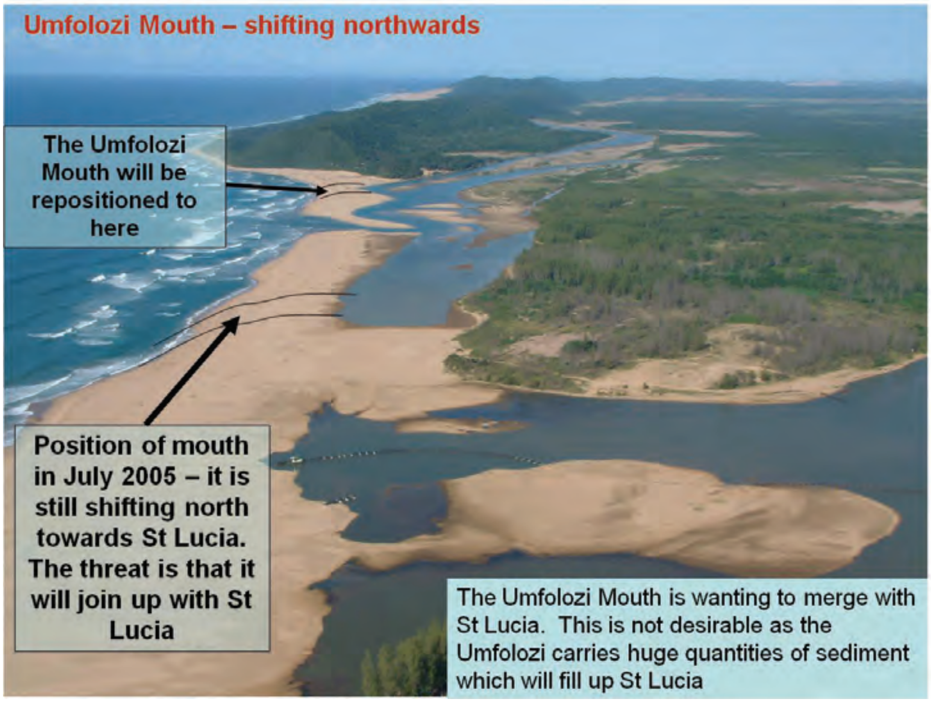

Figure 32. The plan to close the Mfolozi Mouth and reposition it nearer Maphelane.

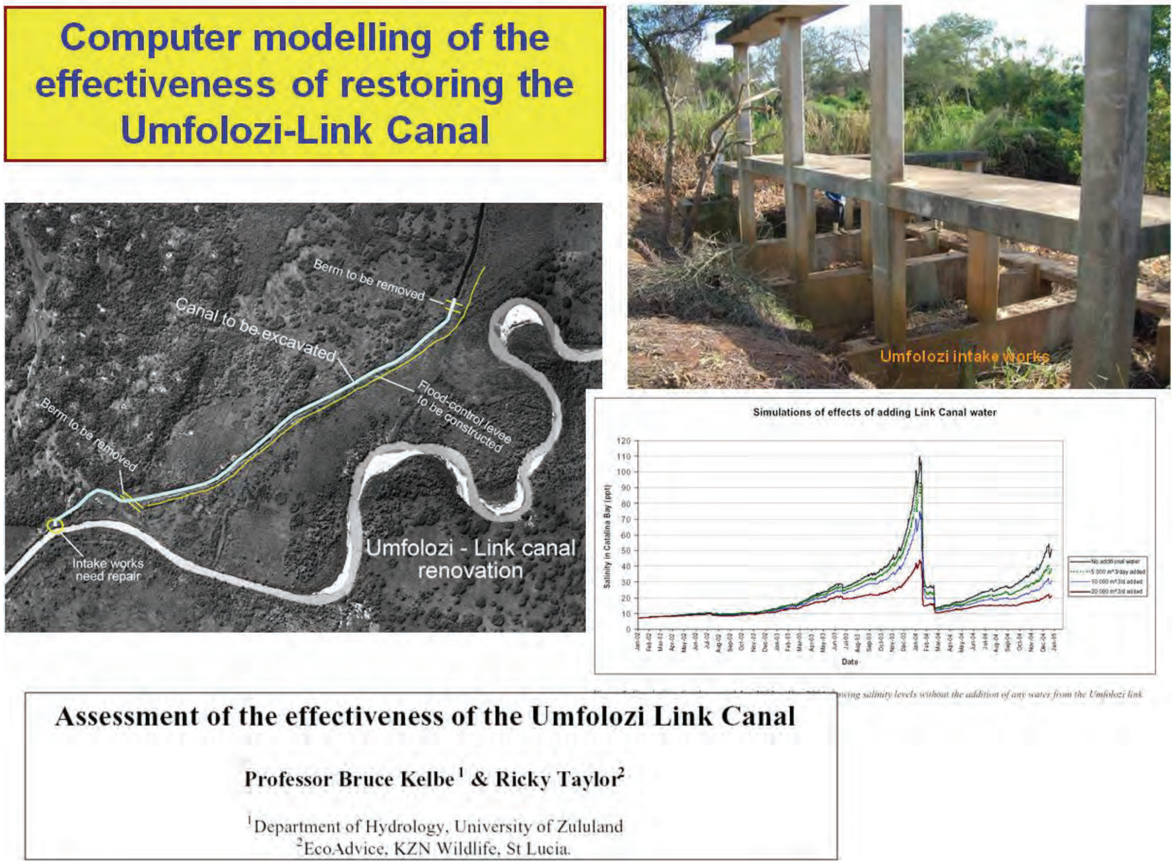

Figure 33. Assessment of the Link Canal and whether it should be restored. Inserts: Top right: The Intake Works after clearing of vegetation and moving of some of the sediments . Left: Indicating the section of the canal that would need to be excavated and the plug that would need to be removed. Lower right: Graph of the various scenarios of salinity in Catalina Bay that could be expected given the operation of the canal. Bottom: Title of the report on the asssessment.

3.8 Timeline for 2006

January 2006:

Water level dropping and there were dust storms where the lake was dry.

Vandals damaged machinery on beach to prevent EKZNW from stopping the Mfolozi from linking into St Lucia. There was concern about huge influx of seawater should the Mfolozi create a combined mouth – bringing in with a lot of sediment.

February 2006:

First record of the alien snail *Tarebia granifera* from the system.

'Working for Wetlands' was building the Tshanetshe weir. This is still part of the repair work relating to the canal in the Mkhuze Swamp excavated during the drought in 1972

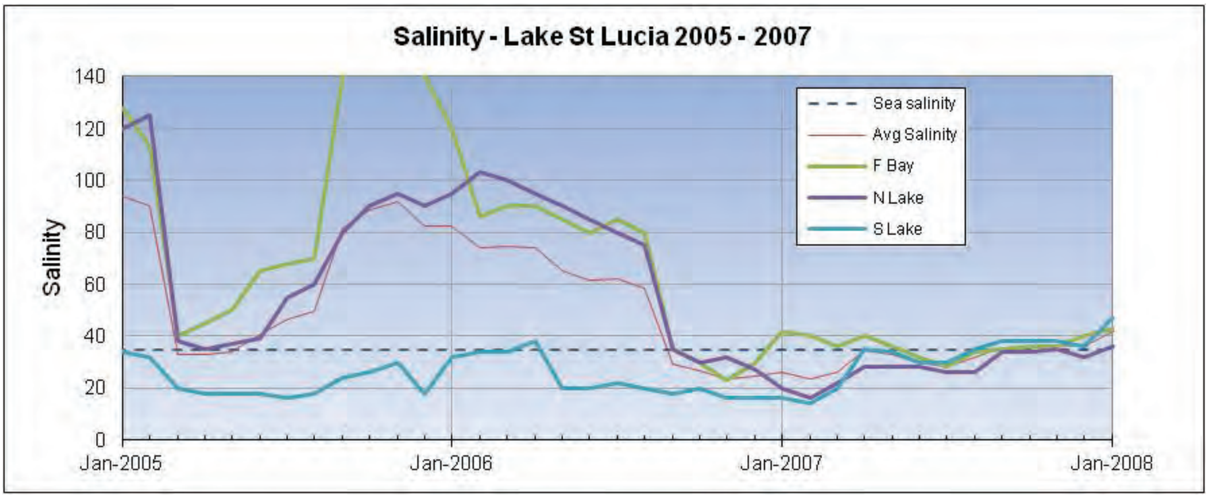

Figure 34. In 2006 salinity conditions started off being severe. The graph is anomolous as parts of the system were dry and the salinity figures were not properly representative of the northern parts of the system.

March 2006:

Assisted the Mfolozi River to close near St Lucia – then breached it near Maphelane

May 2006:

"We have successfully closed the Mfolozi mouth. We have prevented the sea breaching into St Lucia. We have opened a new mouth near Maphelane. This has been a very large job. We used land-based equipment as well as the dredge." (Figure 35).

July 2006:

The Lake basin was a dust bowl as 65% of the lake surface area was dry (Figures 36 and 37).

August 2006:

Produced the document "St Lucia – the big picture" which puts the current drought into the regional context.

A 3.5 m crocodile was captured on beach at Cape Vidal. Possibly it had been displaced from a dried pan on the Eastern Shores.

September 2006:

A hovercraft was bought for the Anti-Poaching Unit to improve access.

Members of the public were caught feeding crocodiles in the Mouth area – to lure them closer to tourists for photos.

October 2006:

Mfolozi Mouth was migrating northward at rate of 2.8 m/day

Figure 35. The closure of the Mfolozi about to be effected.

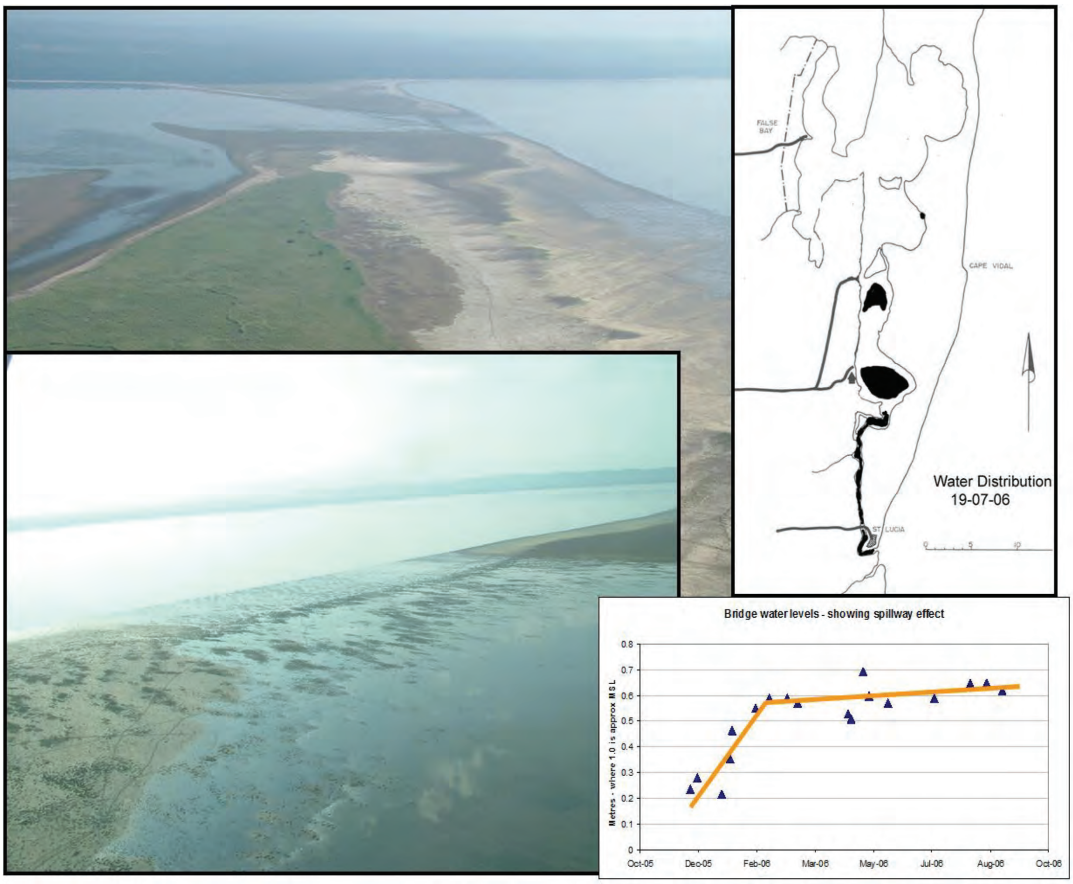

Figure 36. The system first segmented into several discrete basins of water, then the northern parts of the lake dried up. The insets on the left are of the natural “spillway” that separates Makakatana Bay from South Lake. The graph of water levels in the Narrows shows when this “spillway” comes into effect allowing water levels to build up to the height of the “spillway”, then overtopping. As water flows northwards, the water in the Narrows is

maintained at a fairly constant level. The map in the upper right shows the distribution of water in July 2006.

Figure 37. Dust storms occurred when the wind picked up the fine sediments from the dry lake bed. A store room at Listers Point covered in dust from the lake (Photo Jos Ackerman). This dust contains about 4% (by mass) of salt.

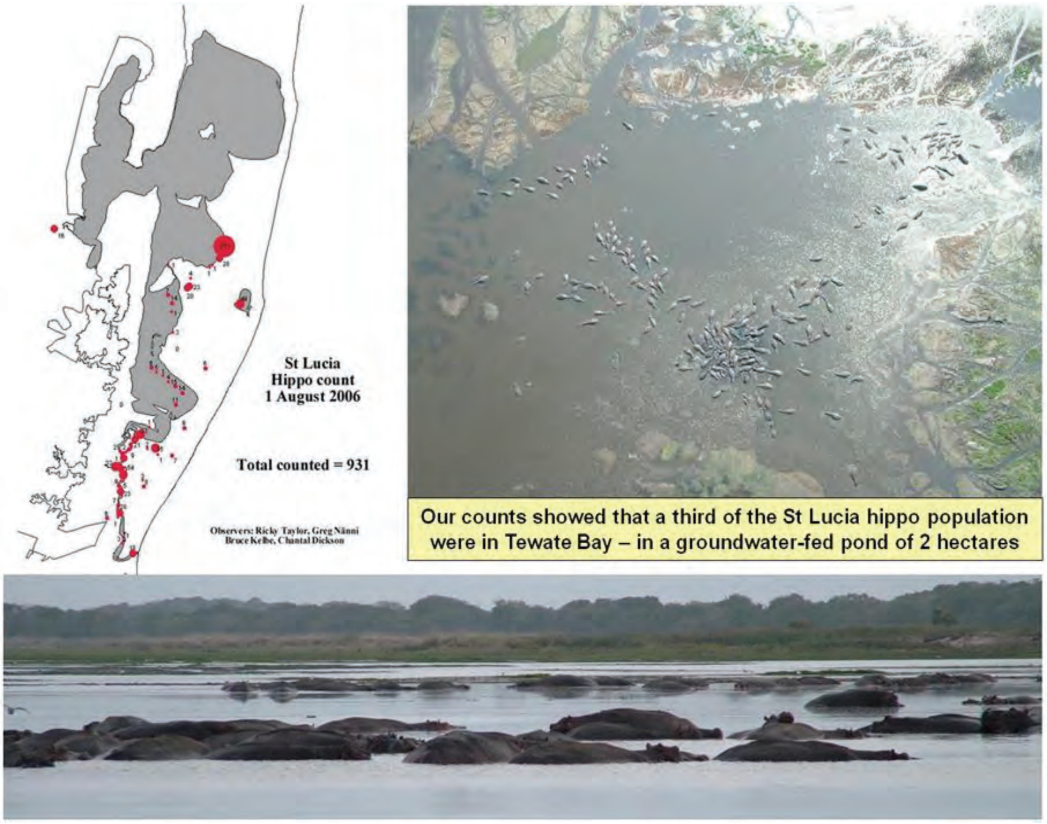

Figure 38. Virtually all the hippos in North Lake and adjacent pans congregated in Tewate Bay where groundwater seepage maintained a small pool of water. (Photo R Taylor)

Figure 39. Fish were still being caught in Catalina Bay in 2006. Here is a kob caught at Charters Creek on 5 August 2006. Note the good condition of the fish. (Photo R Kyle).

December 2006:

Figure 40. By December 2006 virtually the whole of False Bay and North Lake were dry. This photograph was taken over False Bay Park. Listers Point is central in the photograph, and beyond it is Hells Gate. (19 December 2006, I Porter).

Mid-December. Heavy rains in the catchment flooded the low-level bridge on the Mfolozi at Mpila in the Hluhluwe-Imfolozi Park.

Figure 41. Debris, carried by the Mfolozi in flood, on the St Lucia beach. (Photo R Taylor).

Management

- Concern was expressed about the extent of sugar farming that was occurring in the Mkhuze Swamps. (Figure 42).

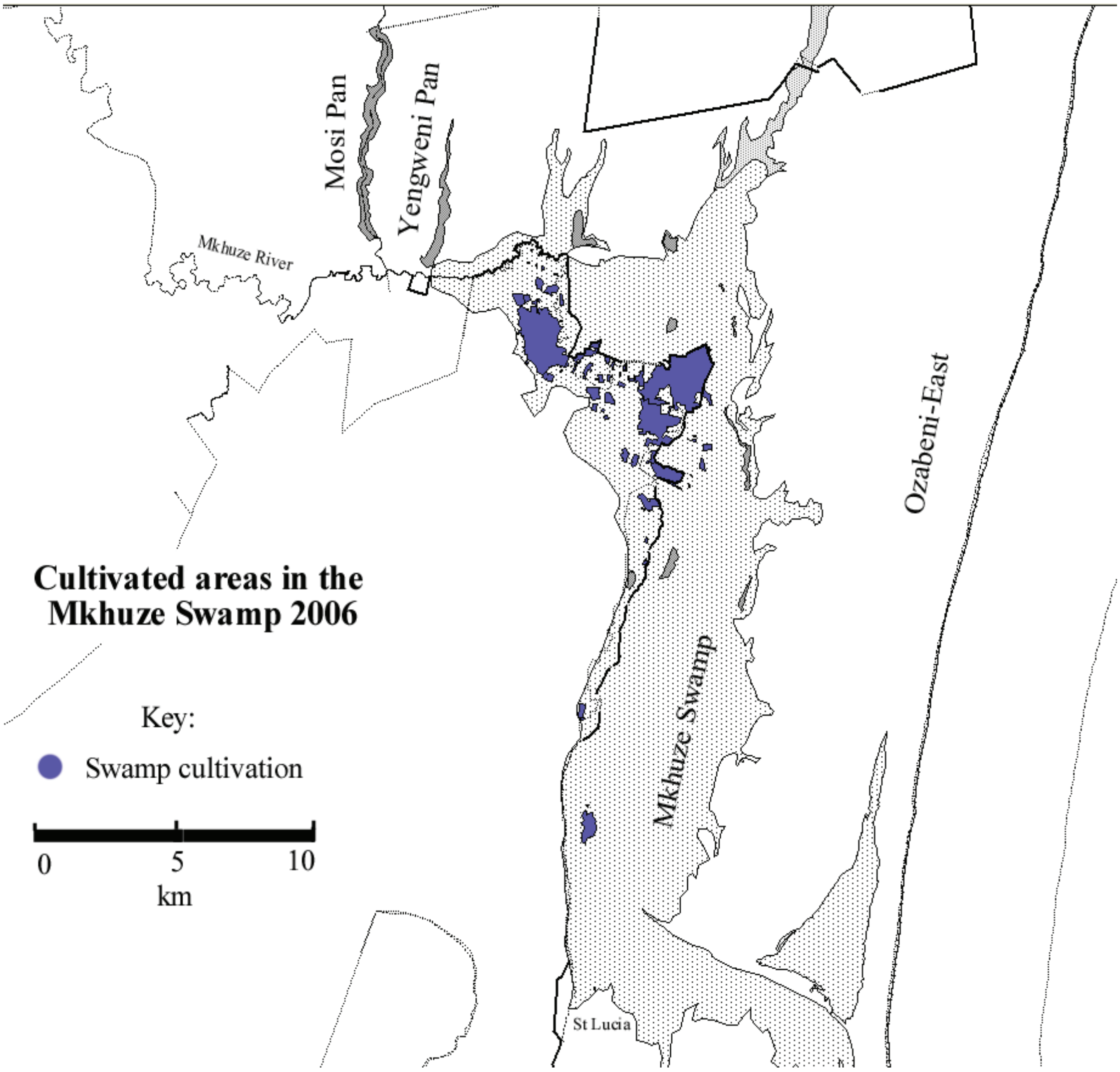

Figure 42. Map of the Mkhuze Swamp showing main areas of cultivation. The cultivation is mainly outside the boundaries of the park, but has changed from low-impact subsistence farming to high-impact commercial cane fields. Unfortunately half swamps cannot be conserved, and altered floodwater flow patterns, caused by the fields, will affect the whole swamp.

Figure 43. The lowered water levels created suitable habitat for estuarine plants. The upper left insert shows groundwater seepage from the Eastern Shores in the Dead Tree Bay area, colonised by sedges, rushes and grasses. Upper right: Submerged macrophytes thrive in shallow clear water with little wave action as in the area north of Honeymoon Bend. Lower left: Measuring the density of succulent salt marsh at Makakatana Bay. Lower right. In the upper part of the Forks there was a rich variety of emergent plants.

3.9 Timeline for 2007 – The mouth breaches, and then closes six months later

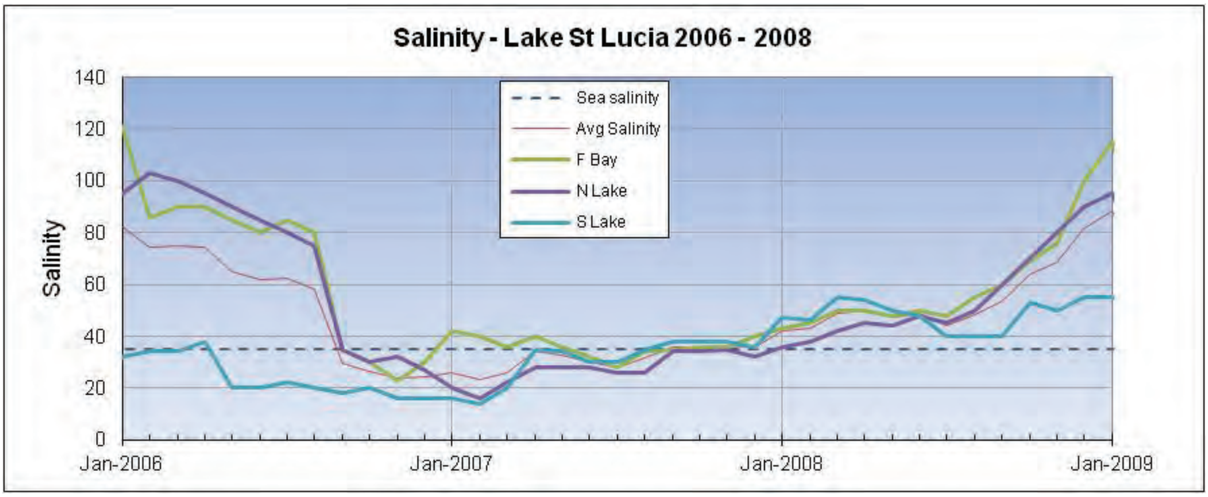

Figure 44. Salinity was reduced to that of seawater over much of the year – aided by the breach of the mouth in March 2007.

January 2007:

Since opening, the Mfolozi mouth had migrated 500 m. This is an average rate of 1.9 m per day. "The Mfolozi Mouth is currently (10 January 2007) 850 m from the berm where we closed the Mfolozi the last time" (Figures 45 & 46).

Figure 45. The configuration of the two mouths in January 2007.

Figure 46. Regular mapping of the north bank of the Mfolozi Mouth using a GPS shows how it advanced northwards at a constant rate.

Beds of *Stuckenia* in the Narrows and healthy *Phragmites* along its shoreline.
Heavy rains raised the lake level.
Water level had risen to give an increase from 30% to 50% area coverage, and all the lake compartments were now linked.
The below average rainfall trend changed in April 2006 and since then, although there had been months with below-average rainfall, there were above average rainfalls in August, October, November and December. As a result of these rainfalls the rivers had started to flow, and by the end of December the Nyalazi and Mzinene were flowing strongly into the Lake. The Hluhluwe River had been flowing into the Hluhluwe Dam – which was 15% full in November, and by the start of January had filled to 55%.The Mkhuze had its first flows under the Lower Mkhuze Bridge in about 5 years in early December. Then with the December rains it overtopped the new Ophansi Bridge in Mkhuze Game Reserve on at least three

occasions. It started flowing strongly under the Lower Mkhuze Bridge on 19 December. The Mkhuze Swamp basin is large and takes a lot of water to fill up. By the 3 January the Mkhuze water had not yet reached Lake St Lucia, but by 12 January a strong flow was entering the Lake. With the rising water level in the Mkhuze Swamp, a large number of fields – some of commercial sugarcane had been flooded.

Charters Creek was once again open to day-visitors. However the camps of Charters Creek and Fanies Island remained closed as there was no freshwater to keep them running.

February 2007:

In early February, good rains in the upper Mkhuze Catchment again filled the Mkhuze River, ensuring a continuous and strong flow into St Lucia.

The Mfolozi River had been flowing well most of the time since 5 December 2006. On several occasions in late December and early January it had flooded, overtopping the weir at Riverview which diverts excess water into the Msunduzi River. Under these levels the water also overtops from the lower Mfolozi into the Link Canal downstream of the Intake Works. This added a considerable amount of water into the Narrows, but came with the cost of bringing in large quantities of very fine-grain sediments.

The Mfolozi sediments turned the waves in the sea a chocolate colour. This is the catchment topsoil that has eroded, and been carried down the Mfolozi River. In the past these sediments would have been trapped in the Mfolozi Swamps, but nowadays are carried through the canals that drain the sugar fields, all the way to the sea.

The lake water now covered an estimated 70% of the surface of the whole lake. The water-body was no longer separated into discrete compartments – except at the Makakatana natural “spillway” which separated the Narrows from the rest of the Lake.

Since 2004 the Lake had been lower than the Narrows. The flood overtopping from the Mfolozi in December 2006 temporarily raised the water level in the Narrows, but this had since dropped as water flowed northwards into the Lake. It reached equilibrium at the level of about 0.6 m on the bridge gauge-plate. The drought was at its most severe in the periods when the water level in the Narrows fell below the 0.4 m level. During these periods, such as in September to December 2005 the evaporation in the Narrows exceeded water gains resulting in the severe drop in the water level.

The salinity figures throughout the system were now much lower than expected. It is believed that a considerable amount of salt had been blown out of the system by the wind, and also that salt had been trapped in the sediments of the lake bed. We do not know how much dust had blown out of the system. Residents in Hluhluwe town complained about the dust blowing into their houses. Figure 47 shows dust accumulated on the lake margins at False Bay.

Figure 47. Dust from the lake bed blowing across a road at False Bay. A significant quantity of material was moved within, and out of, the system by the wind. In the system it accumulated against patches of vegetation forming mounds. (Photo R Taylor)

Normally no submerged water plants grow in the Narrows. But, with the Mouth closed there had been a lowering of salinity and the stopping of tidal or wind-induced currents. Beds of submerged water plants had been growing. In December 2006 these were mainly the plant *Stuckenia pectinata* (Figure 9), but there was also *Ruppia cirrhosa* and *Najas marina*. In Makakatana there were *Stuckenia pectinata*, *Ruppia cirrhosa* and *Lamprothamnion* sp. In Catalina Bay there were mainly *Stuckenia pectinata* with traces of *Ruppia cirrhosa*. In Dead Tree Bay only *Ruppia cirrhosa* was recorded in December.

Figure 48. Aerial photograph of vegetation in the Narrows between Honeymoon Bend to the left and the Mullet Close jetty (bottom right). Note the dark circular patches of *Stuckenia pectinata*. Also note the lush growth of *Phragmites* reeds fringing the Narrows and on the oyster-bed islands (mid-left). The water is discoloured by the sediment-laden Mfolozi water that flooded into the Link Canal (the outlet of this is top left). (12 January 2007, R Taylor).

On the mud flats and exposed shorelines, the rising water levels had now submerged some of the salt marsh areas – covering the succulent *Salicornia* and *Sarcocornia* plants as well as the saline lawns of *Paspalum vaginatum, Sporobolus virginicus* and also the sedges associated with groundwater seepage. These flooded vegetation areas attracted numbers of waders and ducks. The warm shallow water, rich in food provided shelter for small fish (mainly *Oreochromis mossambicus*).

In the Narrows the mangroves were still about 50 cm above the water level. They were dry but healthy.

Fish populations continued to be severely affected by the closure of the mouth which prevents movement to and from the sea for spawning. Those fish that were able to breed were multiplying rapidly (e.g. Tilapia) and small fish were very abundant in the shallows. The long-lived fish were still healthy. Kob and grunter were often seen and there were still some sharks and rays in Catalina Bay. The brack-water prawns (*Macrobrachium* spp) were abundant in places – especially where there was shelter.

For the past couple of years about a third of the total hippo population (318 of about 900 hippo) had been in the Tewate Bay in a basin of about 3 ha in size that is fed by groundwater (Figure 11). Grazing had been good – especially in the rich pan-bottom grasslands, but there had been almost no freshwater north of Tewate.

The crocodiles in St Lucia were stressed – as there had been little water and little fish food for them. Many of them were in the Narrows. For the second year running the crocodile nest surveys showed low nesting numbers. All the nests were in the southern parts of the Lake.

What had been achieved by keeping the mouth closed for the past five years? The main achievement had been the prevention of seawater flowing into the system – and so five years of inflowing salt had been avoided. Had the mouth been open all this time, well in excess of 20 million tonnes of salt would have entered the system by then. In addition, the influx of large amounts of sediment had been avoided.

March 2007:

Combined extreme tides and high seas and effects of Cyclone Gamede caused the mouth to breach on 2 March. (Figures 49, 50 & 51)

The breach was caused by the combination of very high seas caused by Cyclone Gamede south of Reunion Island, a strong onshore wind and spring high tides on the afternoon of 2 March. The waves washed over the whole beach area in front of St Lucia Mouth. The inflowing water eroded several gullies, and where the beach was at its narrowest, the mouth breached in the early hours of 3 March. "With each successive high tide since then the mouth has eroded wider and wider – and is now more than 100 m wide. A large amount of water enters at each high tide and moves northwards into the lake. We estimate that in excess of 3 million cubic metres of water have entered the lake each day since the breach – carrying dissolved in it 125 000 tonnes of salt each day. In the week since the breach the lake level has risen by an estimated 10 cm".

In hindsight, the breach was encouraged by the sand-trap excavated into the beach berm by the dredge a few years previously. This created a steep slope into which the overtopping sea eroded.

Figure 49. Heavy seas breach the mouth of St Lucia in March 2007.

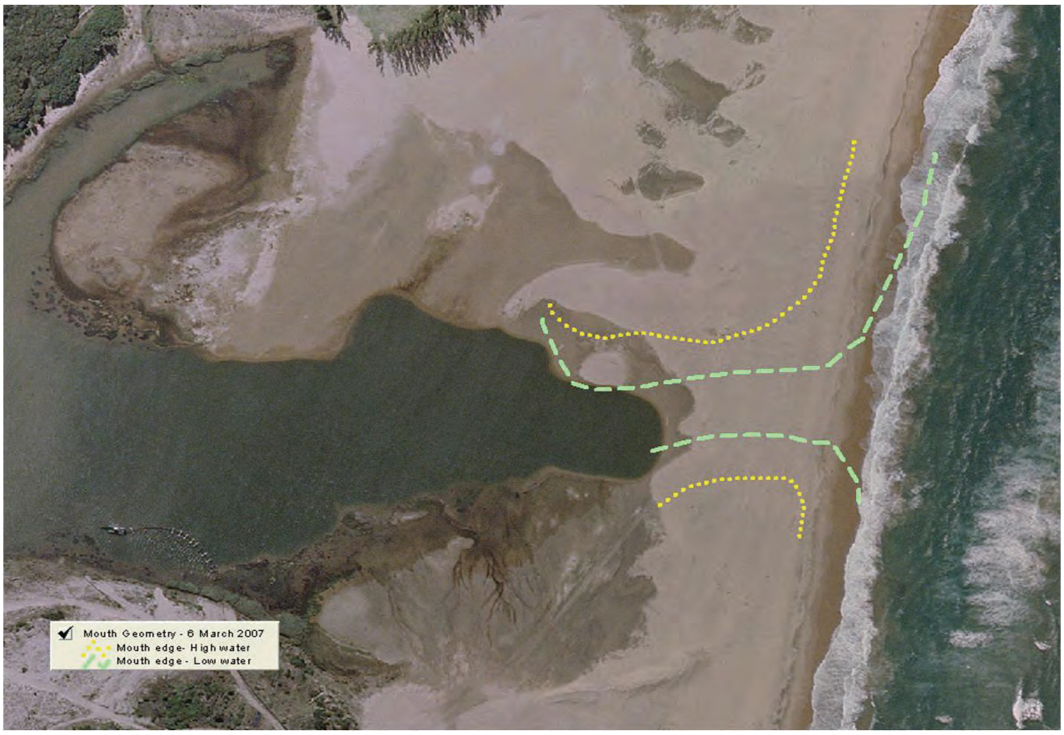

Figure 50. The position of the breach showing the margins of the inlet at high (yellow) and low (blue) tides. The breach possibly would not have occurred had the sediment trap not

been dredged. The cut into the Beach Berm created a weak spot which eroded as the water overtopped.

"In the Narrows water levels have risen by 10 cm at low tide to 70 cm at high tide above what it was prior to the breaching of the mouth. Salinity varied from 34 ppt near the mouth to 30 ppt at Potters Channel (measured on the morning of 5 March). Much of this incoming seawater is moving up the Narrows and is flowing over the natural "spillway" at Makakatana into Catalina Bay. To date there has not been a large increase in Lake water levels as it has such a large surface area. It is likely that the lake will fill over the next six weeks or so, to an equilibrium level which will be a bit lower than mean lake level. If this happens, about 5 million tonnes of salt are likely to enter the system – more than doubling what is in it at present."

"The Mfolozi Mouth is intact. There was a lot of overtopping of the beach berm – with the water then flowing out through the mouth. This caused a lot of salty water to penetrate up the Msunduzi. A local farmer has reported dead catfish (*Clarias*) in the Msunduzi opposite his farm (which is one of the lower farms). These fish die in salinity of a little over 4 ppt."

"Two weeks after the mouth breached, we had the highest seas for many years (said to be a 1:50 year event) combined with extremely high equinox spring tides (resulting in the highest tides in 18 years). This just flattened the whole beach all the way from Cape St Lucia to Kosi – undercutting dunes and scouring away sand. The St Lucia mouth at high tide was the whole beach area in front of the mouth area as waves washed over entering the estuary. This brought in large quantities of sea water. The out-flowing water was much less, and contained to a channel of 60 to 80 m wide."

The high water conditions and the penetration of salt water killed trees such as *Bridelia micrantha,* wherever the water overtopped into the swampland adjacent to the Msunduzi.

At the Mouth Management Meeting of 16 March it was noted that it was important to dredge the sand trap to reduce the sediments that would penetrate into the system.

It was also decided that no effort would be made to close the mouth and that it would be left alone at this stage.

May 2007:

There had been strong currents – of up to 2 m s^{-1} – on a strong incoming tide. These were measured by Prof Derek Stretch. He estimated that during spring tides about 1 million cubic metres of water entered the system. It was less over neap tides, and affected by wind conditions.

Figure 51. The St Lucia mouth stayed open for 6 months after breaching. In that period a considerable amount of water entered St Lucia. The mass of salt in St Lucia doubled in that time.

The inflowing tide (flood tide) lasts for about 4 hours, and the outflowing tide (ebb tide) lasts for about 8 hours. This means that the channel width changes from inflowing to outflowing tide. We measured the mouth to be 45 m wide on outflowing tides. It is interesting to see that a sand bar formed off the mouth. “This could still lead to closure of the mouth in a few months from now”.

In St Lucia the water levels had risen so that much of the lake surface was now inundated, and there was a salinity of 35 ppt in the southern areas and up to 40 ppt in False Bay.

June 2007:

Flow in the Mfolozi River had been extremely low since July, and the Mfolozi Estuary closed naturally in the last few days of July (neap tide).

August 2007:

St Lucia Mouth closed on 24 August, on a neap tide, after having been open for 175 days (and “now still flows in as it overtops at high tides”).

This raised the water level to just below MSL, and the mean salinity of the lake at closure was about 31 ppt.

The Mfolozi Mouth opened naturally on 29/30 August 2007 (spring tide) after having been closed for a month.

At the time there was no problem with the Mfolozi flowing into St Lucia via the Back Channel. However, concern was expressed that a problem would occur if the Mfolozi came down in spate – carrying with it organic debris and high loads of sediment. It is best if these do not enter St Lucia. “We should realise that the longer the Mfolozi remains closed, the higher the beach berm will build up – to a height of about 3 m above mean sea level if left for long enough”. It was recognised that we would need to strengthen the low-lying area on the seaward side of the wall built two years previously to separate the Mfolozi from St Lucia. “We should also consider excavating a low point on the beach near Maphelane to create a weak point over which floodwaters can spill into the sea should the Mfolozi come down in spate. This should be as close to Maphelane as possible – but will need constant deepening as wind-blown sand accumulates”. (27 August report).

September 2007:

As expected, catch data and the sizes of prawns and crabs recorded suggested a recent influx of penaeid and other marine species into St Lucia during the previous seven months since the opening of the mouth during heavy seas on top of equinoctial spring tides in March. *Penaeus indicus*, *Metapenaeus monoceros* and to a lesser extent *Penaeus monodon* were common in the Narrows up to Potters Channel but interestingly were not caught in the Lake at the time of the survey. Likewise sub-adult *Scylla serrata* were also found in the Narrows.

The most abundant prawn species in the lake was an unidentified *Palaemon* sp. which occurred from Makakatana in the south to Lister Point in the north. It was particularly common on the western shores of the lake between Fanies Island and The Coves (Mbizetsheni) with very high densities being recorded in the latter area. Only one *Macrobrachium* was collected – in the Shark Basin inlet

Fish catches indicated that species with marine associations occurred throughout the Estuary and Narrows with *Ambassis* sp., *Pomadasys olivaceum* and *Heteromycteris capensis* being evident whereas the samples throughout the lake were dominated by *Oreochromis mossambicus* and to a lesser extent *Monodactylus argenteus*, both the latter species being generally associated with low salinity conditions in closed estuaries. These were still seen to be persisting in the Estuary and Narrows as well.

November 2007:

The new park name, iSimangaliso Wetland park, was gazetted on 11 May 2007, and applied from 1 November 2007

In the Narrows the *Stuckenia* beds were gone. The fringes of *Phragmites* were grey and dead in response to the high salinity.

There were now huge numbers of small *Oreochromis mossambicus* along the shorelines and in flooded vegetation in the lake.

Emergent vegetation was providing shelter and food (which was missing at very low water levels) in the lake.

Freshwater seepage had encouraged a lot of emergent macrophyte growth.

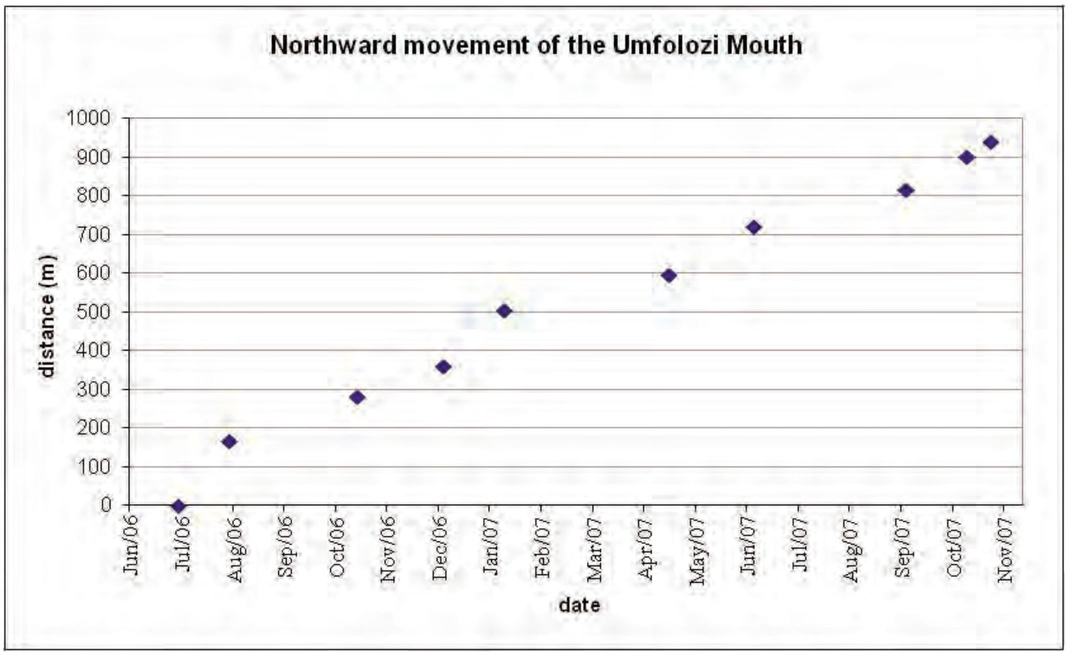

Figure 52. Graph showing the northward movement of the Mfolozi Mouth.

December 2007:

With the rivers flowing, but not too strongly, the lake water level had been increasing slowly. What was interesting was that the water was now covering much of the vegetation along the eastern shoreline that expanded into the lake bed when the lake was at its lowest. The vegetation that is sensitive to flooding, or salt, had died (e.g. *Sarcocornia* and many of the sedges) creating detritus deposits. The more robust plants – such as *Juncus kraussii* and *Paspalum vaginatum* survived the inundation and are emergent. Where the *Paspalum* was under water it had lost its leaves (rotted off or eaten off by fish?), but the above surface bits were healthy. The stems of the plants were covered in algae. The shoreline was rough and vegetated – not the smooth wave-washed beaches of the past.

Figure 53. Photograph taken on 12 January 2007 showing the fields that had been ploughed in the middle reaches of the Mkhuze Swamps. Although this is outside the boundary of the Wetland Park, ploughing in wetlands such as this is illegal. If this persists and expands, it will result in altered drainage through the swamp and an eventual loss of the sediment trapping ability of the swamp. The sediments in the Mkhuze River will then be deposited in Lake St Lucia.

Figure 54. Flood protection may be needed to prevent overtopping of the Mfolozi River into the Link Canal.

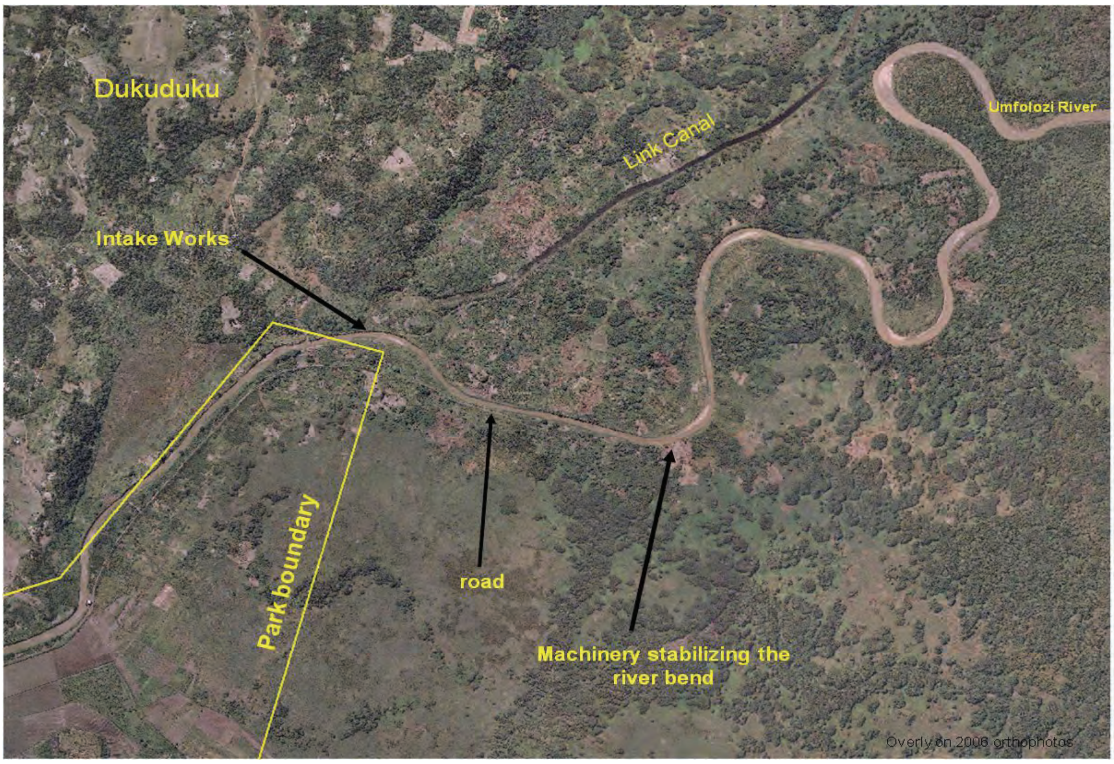

Figure 55. The UCOSP had been building up the south bank of the Mfolozi River to prevent it from breaching southwards and flooding sugarcane fields. This action prevents the southward channel switching of the river.

3.10 Timeline for 2008

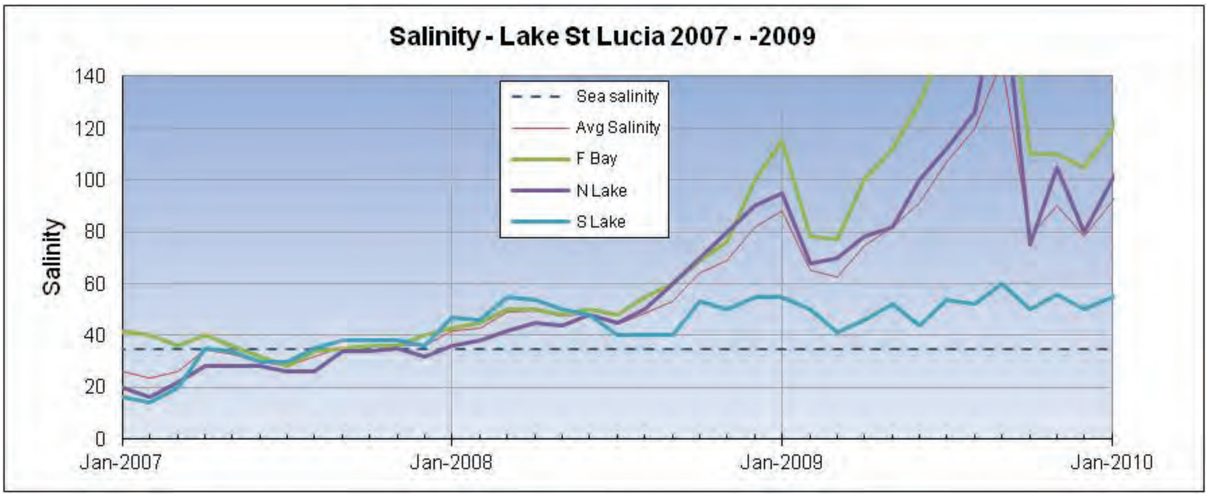

Figure 56. With a greater quantity of salt in St Lucia, the system was more sensitive to water losses.

January 2008:

Figure 57. Emergent plants along the margins of the lake created ideal nursery conditions for fish and crustaceans. Old jetty, January 2008.

February 2008:

Suspected botulism poisoning killed waterbirds at St Lucia sewerage works (Figures 58 & 59). This caused concern because, if it was botulism, then the disease could spread to birds throughout the St Lucia system.

Figure 58. A dead white-faced duck at the sewerage works at St Lucia. A number of dead birds were found, but the cause of death was never confirmed. The dead birds were removed and burnt to prevent spread in case it was botulism.

Figure 59. The hyper-eutrophic St Lucia sewerage works. It is important to be vigilant for diseases associated with nutrient enrichment of water.

A fish die-off was recorded in False Bay. It was not extensive.

There was no sign of *Stuckenia pectinata* or *Ruppia cirrhosa* anywhere in St Lucia at this stage. In the Narrows the reed beds were dying back – this was a lot slower than expected after the seawater influx that occurred while the mouth was open. There were places where the reeds were still remarkably healthy – possibly as a result of groundwater input from seepage sites.

If we were to allow the Mfolozi, without a sediment trap, to link into St Lucia there are several permutations as to how this could be done. However, all involve the introduction of the water with the current sediment loads. Recently there was some questioning as to how bad the sediment could be. We have very poor information about the sediment load of the Mfolozi, but empirically we do know that when the joint mouth closed in 1950, it took 13 years of dredging to remove the accumulated sediment. Not all of this sediment came from the Mfolozi – we now understand that considerable quantities can enter from the sea – especially if the mouth is kept open when there is not a lot of outflow.

There were very large numbers of small fish (mainly *Oreochromis* of about 4-5 cm) and in places the shrimp *Palaemon* is very abundant. In his second crustacean survey, Iain Bickerton found that in the southern parts of the lake the mud crabs, *Scylla serrata*, were once again abundant – all with a carapace size of about 8 to 10 cm (obviously recruited while the mouth was open). Stickbait (*Solen cylindraceus*) were abundant in the Catalina Bay basin; some of about 3 cm long. And the alien snail *Tarebia granifera* seemed to be thriving and was present in large numbers along the eastern shoreline.

The CRUZ team found an abundance of needle fish in the open water of the lake (these indicate a high zooplankton abundance) and these were being preyed on by smallish springer. It seems as if there were not too many large fish in the main lakes. The Narrows seemed to be a different story – with an abundance of fish.

March 2008:

Dredge refurbishment was undertaken (Figure 60). The hull was repaired as it had corroded. Everything was painted.

Figure 60. The dredge in the dry-dock for much-needed hull maintenance.

Figure 61. A plan to bring the winter low-flows of the Mfolozi into St Lucia via the Back Channel.

The Mfolozi mouth closed on March 27th. Managers excavated a weak-link on beach at Maphelane, but did not breach the mouth. Water was flowing through the Back Channel. (See Figure 61)

It was considered that the Mfolozi, on a continual basis, offers estuarine nursery opportunities to juvenile marine species. However, the high density and diversity of fish within the Mfolozi Estuary at that stage may have been because the immediately adjacent St Lucia Estuary had been closed off from the sea since June 2002. This may have resulted in higher than normal recruitment levels into the Mfolozi. Essentially the post-larval fish have nowhere else to go, as the next nearest estuaries (Mgobezeleni and Nhlabane) are a long distance to the North and South of the St Lucia and Mfolozi estuaries (CRUZ report 2008).

Illegal fish net was confiscated in the Narrows. There were 627 fish of 15 species. Tilapia were the most common and the catch included shad.

Penaeid prawns have been abundant – and with the closure of the mouth they have dispersed to the northern reaches of the lake. Anti-poaching exercises showed that large specimens of *Penaeus indicus* and *Penaeus monodon* were being caught.

Figure 62. Measuring fish taken from a confiscated poacher’s net. (Photo J Gerber).

April 2008:

At the Mouth Management meeting of 11 April 2008 it was resolved to artificially close the Mfolozi Mouth (as we have done on several occasions in the past), but, instead of re-opening it close to Maphelane, to keep it closed and allow the Mfolozi water to divert through the Back Channel into St Lucia. It was hoped that the amount of water thus gained would stabilise the St Lucia system. (The modelling by D Stretch indicated that a quantity in the order of 2 m^3s^{-1} will achieve this). At the same time, it was planned to cut a low point in the beach at Maphelane so that, should there be a flood in the Mfolozi, it would overtop there and burst out to sea – thus creating its own mouth near Maphelane. Thus Mfolozi flood sediments would not enter St Lucia.

May 2008:

Moving of the Mfolozi Mouth took place, and the linking of the Mfolozi to St Lucia via the Back Channel occurred. The success of this was assessed.

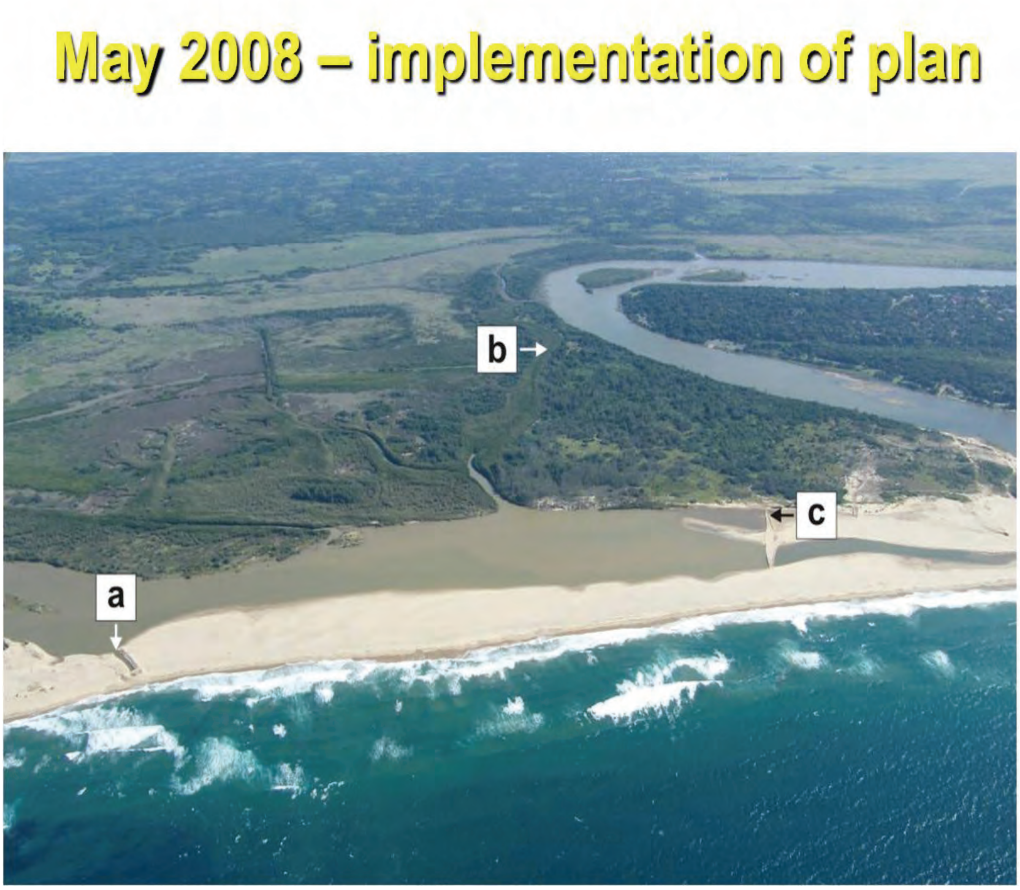

Figure 63. The plan to activate the Back Channel was implemented – by closing the Mfolozi Mouth (c) and creating a "weak link" near Maphelane (a). The backing up Mfolozi water would flow via the Back Channel (b) into St Lucia.

Sand was stock-piled on the banks of the Mfolozi River in preparation for blocking it (Figure 65). Then, luckily for us, the Mfolozi closed naturally on Sunday 27th. As all the necessary equipment was in place, we were able to place a berm across the river on Monday 28th

(Figure 64). Then on the following day we were able to excavate the “weak link” at Maphelane. The berm across the Mfolozi was strengthened and the ‘weak link’ touched up and most of the job has been completed. By Friday morning, the Mfolozi had risen to the extent that the water was starting to push through the Back Channel and into St Lucia (Figure 66). All that remained now is some minor ‘touching up’, and the monitoring of water levels and flows.

Figure 64. Closing the Mfolozi Mouth

Figure 65: Tippers bringing sand to a stockpile area on the beach to be able to close the Mfolozi Mouth. (Photo R Taylor).

This year, instead of immediately breaching the new mouth at Maphelane, water was allowed to flow from the Mfolozi through an old channel into St Lucia – and in this way gained about 3 million cubic metres of water for St Lucia.

Figure 66. The outcome; sediment-free Mfolozi water flowed into St Lucia.

The final phase of this exercise was to breach the new mouth to the Mfolozi near Maphelane. This was done because the upstream sugar farmers were being flooded out by the backing up water. Figure 67 shows Mfolozi water flowing strongly in the new mouth

Figure 67. After the Mfolozi water had backed up too high much and was flooding sugarcane fields, the mouth was breached in June near Maphelane. (Photo R Taylor).

June 2008:

Breached Mfolozi mouth because it is flooding farms.

Before breaching an estimated 3 million m^3 of freshwater had entered St Lucia.

August 2008:

The Mfolozi River dried up completely at Riverview. Digging for water was necessary to obtain the subsurface flow for domestic water supply for Mtubatuba and surrounding districts.

Report on the effectiveness of the Back Channel. This report, contracted by the iSimangaliso Authority and done by Lawrie and Stretch, uses modelling to show the importance of bringing Mfolozi water into St Lucia. Our exercise in allowing water through the Back Channel was useful as at that stage, it had allowed 17 million m^3 of Mfolozi water to enter St Lucia – but this water is not enough. The link between the systems has to be done at a larger scale if it is to be effective during drought periods. We recognised that we had been slowly building up knowledge about how the system functions – and this would be used to underpin any management actions that were to be implemented.

November 2008:

Fixed point photos show lush reed growth at Honeymoon Bend.

Diverted 1.5 mill m^3 water into St Lucia via the Back Channel .

There was a high salt load in the system (from the seawater that entered in the period March 2007 before closing in August 2007).

The system was at that stage very sensitive to increases in evaporation relative to gains in freshwater. Increases in salinity could happen very rapidly.

December 2008:

Rain relief for St Lucia.

Figure 68. There were ever-increasing concerns about the amount of clearing of swamp vegetation in the Lower Mfolozi area to plant gardens.

3.11 Timeline for 2009

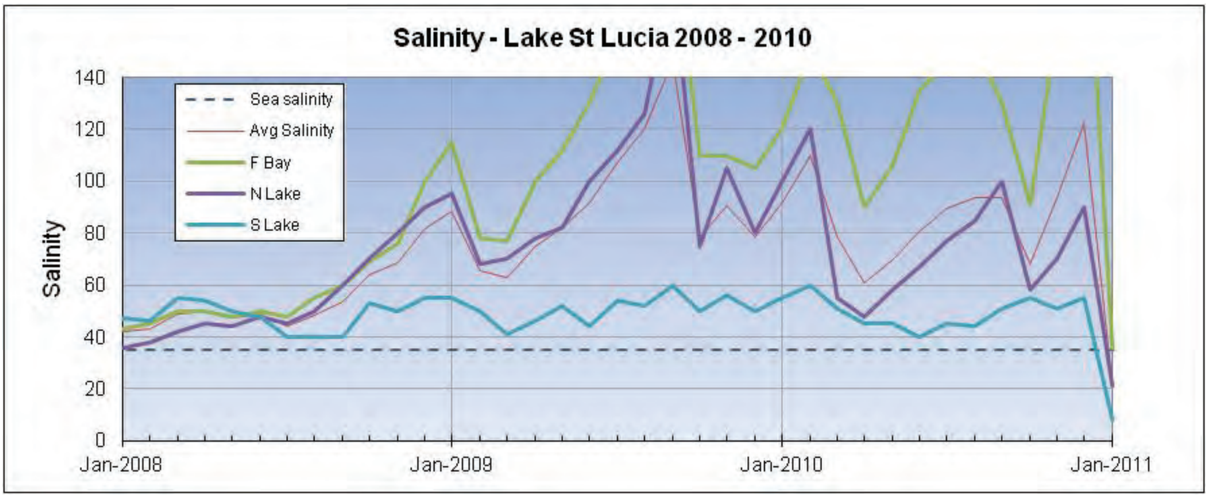

Figure 69. Very severe salinity levels in North Lake and salinity in the 40 to 60 ppt range in South Lake for all of 2009.

January 2009:

System was ‘drying down’, and water levels were receding. This was a rich condition for waterbirds and 15000 were counted in St Lucia during the CWAC count.

Mfolozi mouth breached naturally on 8 January 2009.

Figure 70. The rare plant *Thespesia populnea* now found on the banks of the Msunduzi Estuary at Maphelane. (Photo: Ricky Taylor).

February 2009:

Around 12 February high tides and high seas caused the overtopping of sea into St Lucia for a few days. This would have enabled some fish and invertebrate recruitment to St Lucia from the sea.

A fish die-off was reported from False Bay in January-February 2009. Caroline Fox surveyed this, and found that virtually all the fish were *Oreochromis mossambicus* (Tilapia). These had died over a protracted period, and were still dying. Our assessment was that the high salinity – which peaked at a concentration that is four times as salty as the sea (140 ppt) in January, caused the fish to be highly stressed. The high summer water temperature, in combination with the oxygen depletion that occurs when wind stirs up the sediment, then killed these highly salt-stressed fish.

7000 pelicans counted in St Lucia. They eat more than 10 tonnes of fish per day.

A workshop was held at the St Lucia Crocodile Centre to launch the KZN crocodile research programme

The solution for St Lucia would be to allow the Mfolozi to flow into the Lake again (Whitfield at the symposium 'Implementing Environmental Water Allocations' held in Port Elizabeth, 23-26 Feb 2009).

March 2009:

In the first two days of March the Mfolozi came down in flood (Figure 71). The quantity of water exceeded 80 000 m^3s^{-1}. During its peak (of about 24 hours) it overtopped the spillway at Riverview which shunts excess water down the Msunduzi River. The quantity of water was such that it also overtopped the river banks flooding the lower Mfolozi and also flowing into the Link Canal bringing water into St Lucia. (Figure 72). The water obtained was welcome for St Lucia, but the sediment it carried was not.

Figure 71. The Mfolozi floodwaters at Monzi – where the river is still contained within the artificial levees of the Warners Drain. (Photo R Taylor).

Figure 72. After the flood had again overtopped into the Link Canal there were concerns about the Mfolozi River taking this as a permanent route. The Link Canal is in the upper left of the photo, the meander in the Mfolozi River in the bottom right and the St Lucia Estuary in the upper right.

Started winter with a very low lake level.

As the lake was highly saline then, we cannot explain how the fish populations could be large enough to support the pelicans. To check on this we did some sample netting in Catalina Bay. Fish catches were reasonable – but consisting mainly of springer (*Elops machnata*). These fish are fast swimming and would not be easy prey for the pelicans.

Previously a lot of effort went into closing the Mfolozi Mouth, to make a weak link at Maphelane and to monitor water flows from the Mfolozi to St Lucia. At a management meeting on 11 March the question discussed was "Was it worth it?" The summarised details were:

The Mfolozi closed on 31 May 2008.

The Back Channel link was operational till 5 December 2008 (Figure 74) – when the mouth of the Mfolozi to the sea was artificially breached.

The Mfolozi closed again on 26 December 2008.

The Mouth was breached again on 8 January 2009.

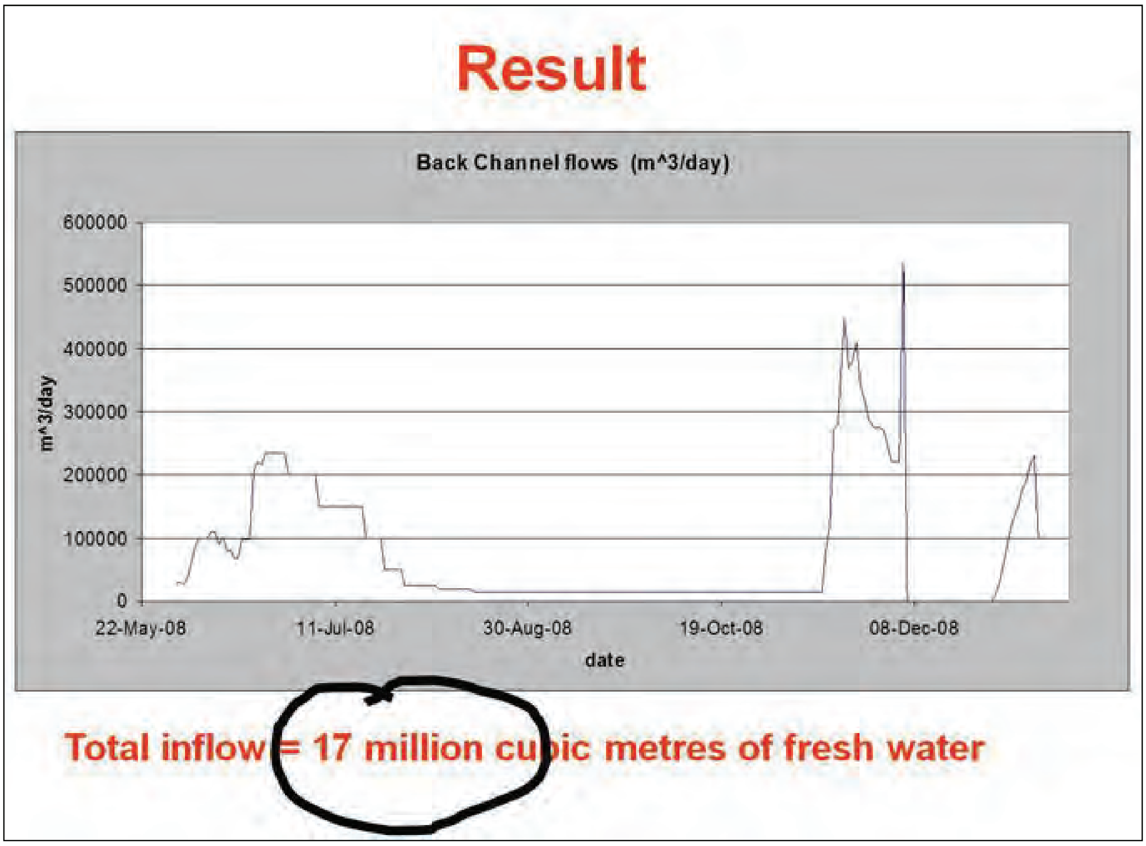

Figure 73. The results of bringing Mfolozi water into St Lucia via the Back Channel from May 2008 to January 2009. This resulted in a gain of 17 million m^3 of fresh water.

Was 17 million cubic metres of water significant to Lake St Lucia?

Quantity was small (i.e. this is 1 to 2 weeks of evaporation losses), but the water was focussed in the Narrows – so it had a local effect. The water was of a high quality (salinity low and no sediment).

The exercise created a mind-set that a Mfolozi-St Lucia link is possible – and important.

The backing up of water affects neighbouring sugarcane famers (Figure 74).

The assessment is that the Back Channel works – but provides too small a relief to St Lucia to be the solution. There must be more flow to justify the closure of the Mfolozi Mouth.

The bigger the volume held in the storage, the more effective the area is as a sediment trap.

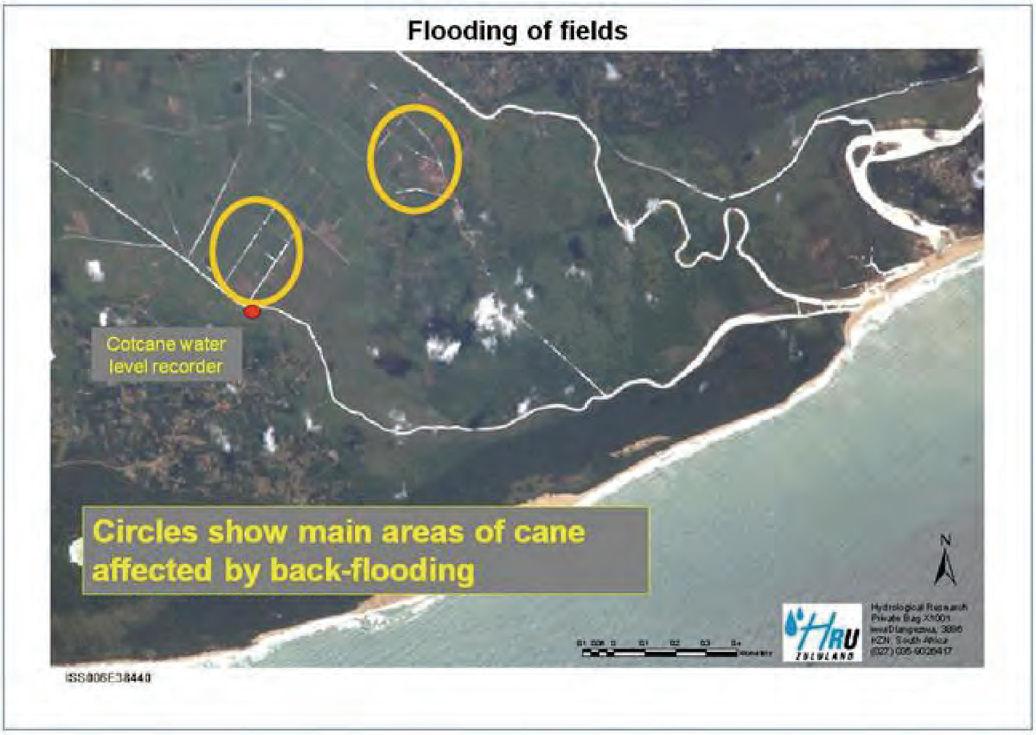

Figure 74. The areas of sugarcane farming affected by back-flooding. The CotCane area is the circle on the left, and the Main Drain farms to the right.

April 2009:

Concern was expressed about the alien invasive plant *Tamarix* which is abundant in the Lower Mfolozi areas and has started appearing in the Narrows and all the way into the Brodies Shallows area (Figure 75).

Figure 75. The invasive alien plant *Tamarix* which was starting to colonise the Narrows. (Photo R Taylor).

July 2009:

There was a huge fish die-off, mainly in North Lake and mainly Tilapia. This was due to unusually cold temperatures (Figures 76 to 79).

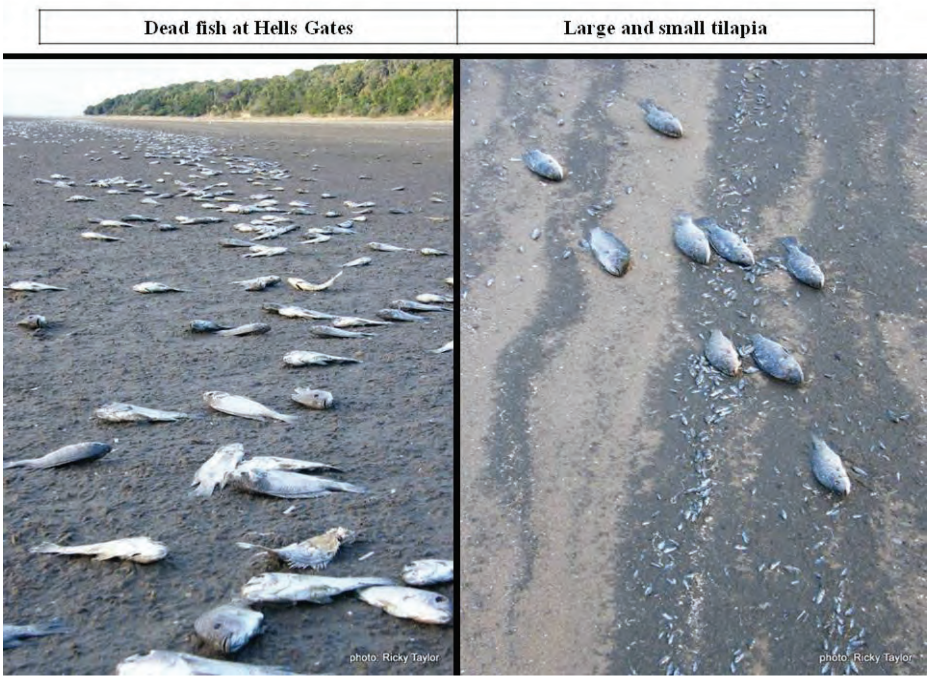

Figure 76. (left). The extensive fish die-off in North Lake in July 2009 after a particularly cold snap. Figure 77 (right). The fish that died were breeding Tilapia as well as juveniles.

Description of the fish die-off:

Types of fish:

In North Lake it was predominantly Tilapia. But there were also small numbers of mullet, springer and, at an early stage, grunter.

At 50 Tilapia per metre of shoreline; approximately 2.5 million fish died.

There were two sizes of Tilapia. Most visible were those of about 20 cm in length, but there were also large numbers of young ones of about 2-3 cm.

In the rest of the lake there were markedly fewer fish. There were mainly slimies (*Leognathus*) at Charters Creek.

The likely cause of the die-off:

Although salinity was high, many of the Tilapia showed breeding colours and looked healthy. So it was not a relatively slow rise in salinity. (Figure 78).

The orange cyanobacterial bloom may have contributed by lowering oxygen levels – but the fish die-off also occurred in places where there is no evidence of the bloom. (Figure 80).

The cold conditions are the most likely explanation. Very cold weather had occurred and Tilapia are known to be sensitive to cold water. The area they died in is shallow and affected by wind pushing water over sand-banks, thus cooling water and then flowing back into the main body of the lake. (See Figure 79 a & b).

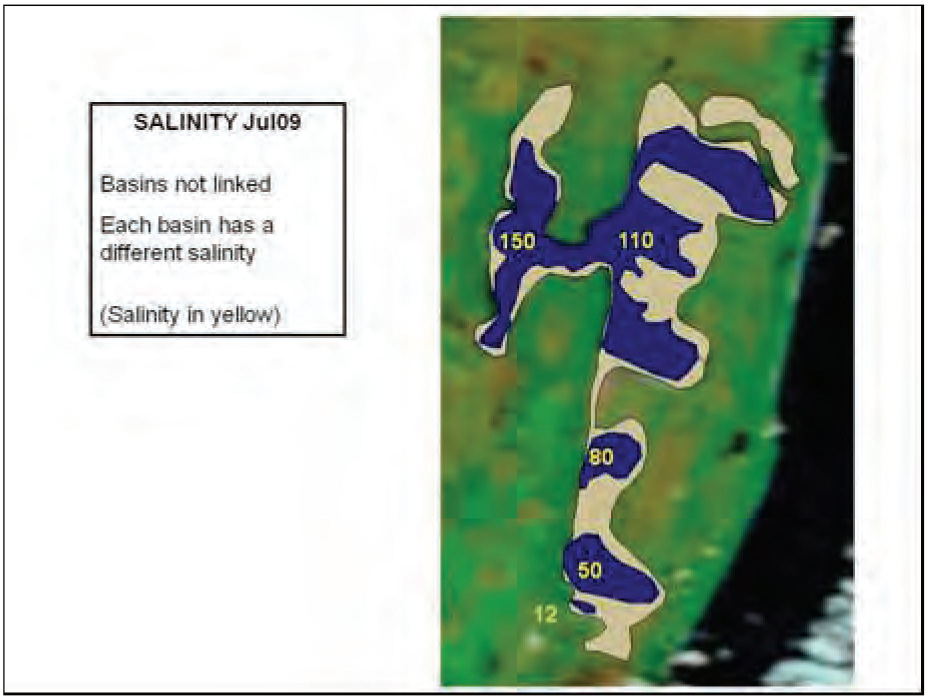

Figure 78. The distribution of water and salinity in St Lucia – July 2009.

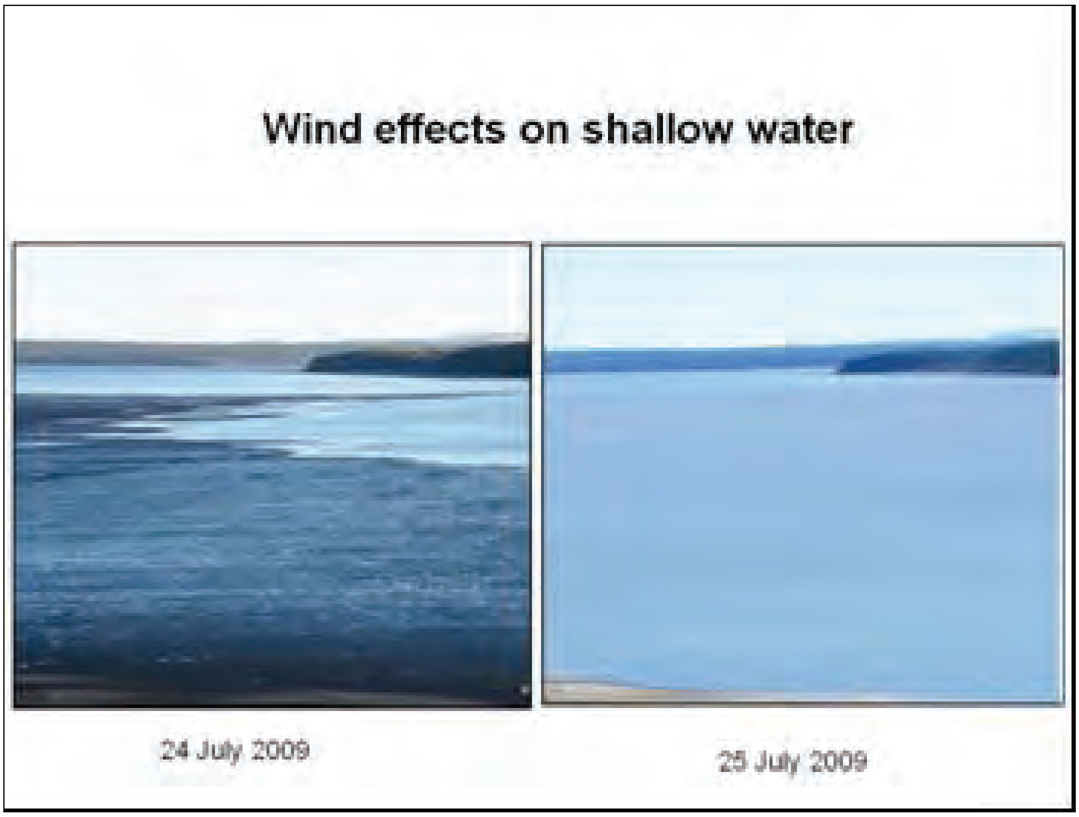

Figure 79 a and b. Photos taken on two successive days from the same point showing the influence of wind from the north (a) and from the south (b). The shallow water cools rapidly during cold weather.

Cyanobacteria bloom in North Lake.

Pelicans were breeding at Hells Gates (250 chicks) – for the first time in 5 years.

Figure 80. The 'orange water' caused by a cyanobacteria bloom in North Lake.

Figure 81. Google earth image of the northern Lake St Lucia (August 2008) showing the extent of the cyanobacteria bloom that discoloured the water. Note also the low water level and how much of the northern parts of St Lucia were exposed.

Figure 82. Aerial photograph from 20th July 2009 showing a constricted Mfolozi Mouth.

This last neap tide the Mfolozi Mouth came very close to closing. We were hoping that it would close. We would then be able to divert the Mfolozi water into St Lucia – which at the time, was desperately short of fresh water.

August 2009:

Water level was particularly low – dividing the lake into discrete compartments (See Figure 78 for the map from the previous month, i.e. July 2009).

Stickbait (*Solen cylindraceus*) dying in large numbers at Hells Gate as the water recedes.

The Mfolozi Mouth was severely constricted and "it may close fully soon" (19 August 2009).

September 2009:

A fish eagle nest census conducted on 12 September showed only 2 nests in the whole of the St Lucia system. This is compared to the 33 nests counted 15-20 years ago. Only 13 adult fish eagles were seen. Under 'normal' conditions the lake supports 90 to 100 adult birds.

Algal bloom persists in North Lake. In places it seems as if anoxic conditions were occurring (Figure 85), but oxygen was not measured.

A new species of benthic anemone was found in the system by Prof. Renzo Perissinotto (This species is now described as *Edwardsia isimangaliso*). (Figure 86)

Salinity: Hells Gate = 200 ppt, Charters = 66 ppt.

The juvenile pelicans were flying.

Figure 83. The larger of the islands off Hells Gates on which the pelicans were breeding. The adults are white and the juveniles are black, becoming brown as they fledge.

Figure 84. Desiccated fish a month after the big die-off. Dryness and high salinity slowed the decay of the dead fish.

Figure 85. Black anoxic mud in North Lake caused by the algal bloom.


Figure 86. The new species of benthic anemone. (Photo Renzo Perissinotto)

October 2009:

About 50% of the lake bed was exposed at the time.

Stuckenia pectinata was thriving in the Narrows

A few emaciated crocodiles were found – some barely alive and there had been some deaths. There was no sign of pansteatitis (which was killing crocodiles in the Kruger Park). There was speculation whether the deaths could have been due to lack of food (for those large crocodiles that had not switched from fish to mammals) or if it was possibly a response to lead poisoning from eating lead fishing sinkers.

Top predators are often the first indicators of stress in ecological systems. Anticipating problems to the top predators the EKZNW, with the UKZN, had launched a research programme to study crocodiles in the whole of Zululand. This programme was going well and would provide information needed to manage crocodiles in increasingly stressed protected areas. A feature of the Zululand Crocodile Research Programme is the synergy that was created having four researchers simultaneously in the field and collaborating with two groups of researchers in the USA, with the scientists in the Kruger Park and with scientists from Mpumalanga and Onderstepoort.

Stickbait (*Solen cylindraceus*) had been most abundant in North Lake and there were large die-offs as the water margin receded exposing and killing these animals. Piles of their shells had been washed up in places (Figure 87) likely killed by the high salinity. At Charters Creek on 2 October 2009 there were between 400 and 600 of these bivalves per m^2 that had died in situ in dried up lake bed. They were all about 4 cm long and were recently dead, having died from exposure and desiccation.

Figure 87. Rising salinity and drying out of the lake bed killed vast numbers of the bivalve *Solen cylindraceus*. This pile of shells was at Hells Gates.

November 2009:

The cyanobacterial bloom was still in North Lake. Weekly monitoring of the algal bloom in the Hells Gate area continued.

A *Microcystis* bloom was recorded in Lake Bhangazi-South. The bloom in Bhangazi was identified as the blue-green alga *Microcystis*. It can produce a toxin that can be kill animals drinking the water.

There was a release of 300 crocodile hatchlings from the Crocodile Centre into the lake. They were all measured and scute-clipped to be individually recognizable. This would possibly give some information on rates of survival. If there are any recaptures it would provide information on growth and movements. This was justified after consideration that well below average numbers of crocodiles have nested in the last few years.

December 2009:

Good early-summer rains, Mkhuze River was flowing into the lake (Figure 88).

Salinity Hells Gate = 80 ppt, Charters = 53 ppt, Narrows = 11 ppt.

Figure 88. The Mkhuze Mouth showing that the water level in St Lucia had risen and it looked as if water was flowing from the Mkhuze Swamp into the Lake. (Photo: Terry Ferguson).

Figure 89. As a result of stable freshwater conditions and the closed estuary mouth the freshwater plant *Stuckenia pectinata* was flourishing in the Narrows. This was providing suitable habitat to be used as a nursery for fish.

After having been open for three weeks, the Mfolozi Mouth closed naturally on 26 December 2009. Once again water backed up into St Lucia via the Back Channel. This brought in a welcome 1.5 million m^3 of fresh water into St Lucia before the Mfolozi Mouth breached naturally on 8 January when flows in the Mfolozi suddenly increased. To put this into perspective, St Lucia looses more than double this amount through evaporation on a single warm and windy day. However, this water freshened up the Narrows and hence was useful to the St Lucia system. It also showed that sediment-free water can be diverted into St Lucia and hopefully this will lead to a larger scheme to bring in more water in the future – re-establishing the original Mfolozi-St Lucia link.

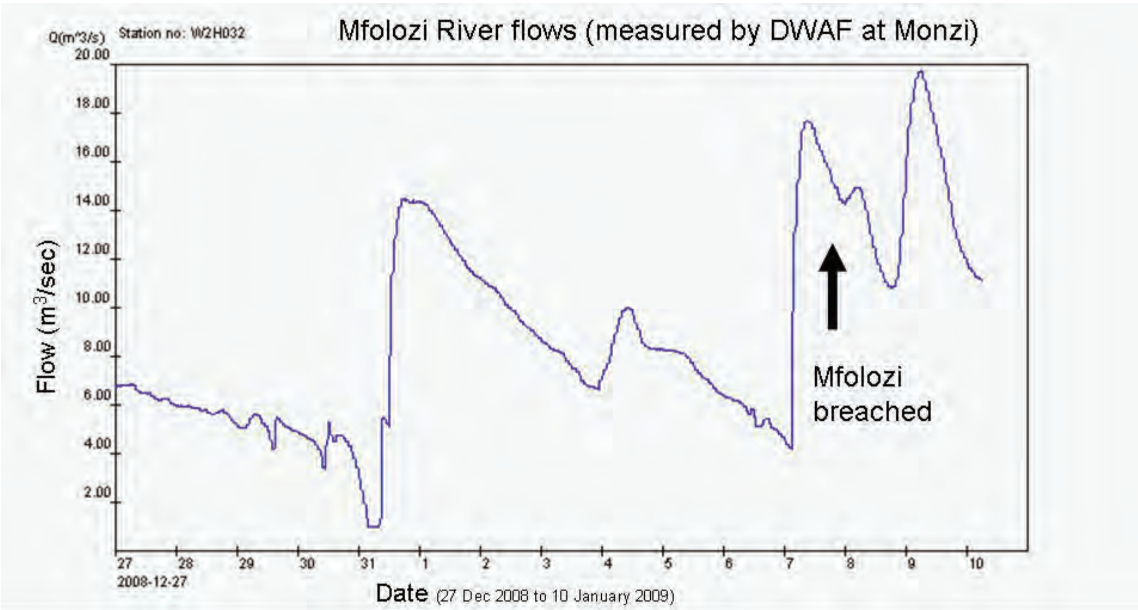

Figure 90. Hydrograph of the Mfolozi River. The Back Channel carries 3 to 5 $m^3 s^{-1}$. As flows were well above this for most of the period the mouth was closed and the water backed up into the lower Mfolozi Swamp. On the 8th January 2009 water levels increased to the point where the beach berm was overtopped and the mouth breached.

Crocodile post-mortems. Dr Cooper, as part of the disease surveillance, and assisted by toxicologist Dr Jan Myburgh and pathologist Dr Johan Steyl from the Faculty of Veterinary Science, Onderstepoort, euthanased two extremely emaciated crocodiles that were unlikely to survive and did thorough post mortems on them. (Figure 91).

Figure 91. A post-mortem examination of an emaciated crocodile. From left to right: Jon Warner, Xander Combrink, Dr Johan Steyl, Dr Jan Myburgh and Dr Dave Cooper.

Comments from crocodile researcher Jon Warner who will be using the results: “We were able to do two necropsies while Jan and Johan were here. Nothing visible suggested anything other than starvation (no lesions, pansteatitis, etc. but some secondary infection), and we should have results from the tissue analyses in the next few weeks.”

Figure 92. There is continuous insideous expansion of the swamp gardening in the lower Mfolozi Swamp. The trend is for them to evolve from subsistance to commercial use. The photo shows swamp forest trees being felled to expand a garden.

3.12 Timeline for 2010

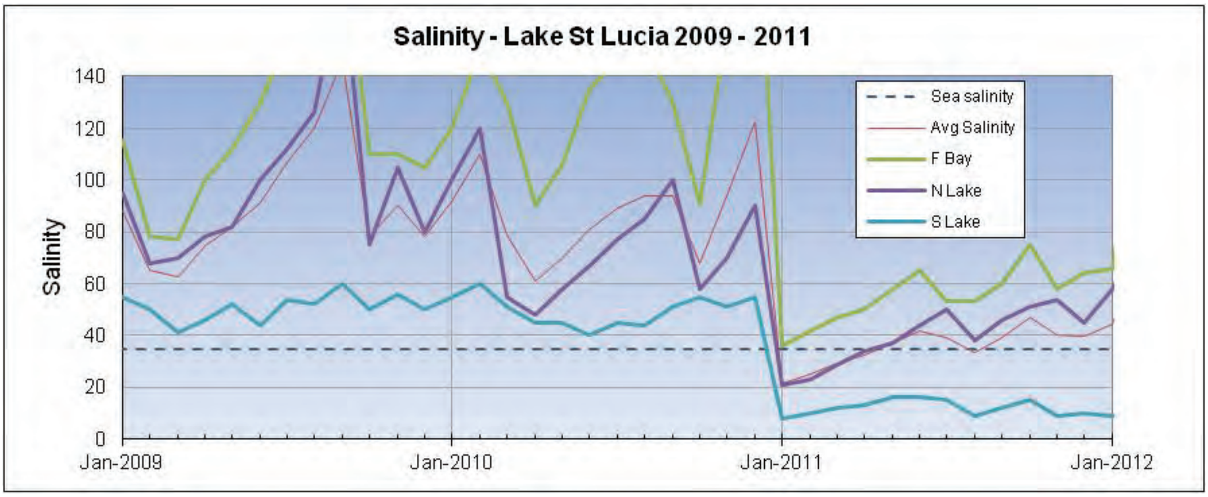

Figure 93. The year 2010 was to be another one of severe salinity conditions.

February 2010:

Cyanobacterial bloom continued in North Lake – it was very persistent.

Mkhuze River was still flowing into St Lucia.

At the Mouth management Meeting of 27 February 2010 it was reported that the Mfolozi Mouth had moved at 1.7 m per day for the last 200 days.

March 2010:

With the low water levels the mangroves in St Lucia had been dry and unaffected by tidal action for some years. This had allowed the alien invasive plant *Schinus terebinthifolius* to colonise in some areas (Figure 94). It is known to have a high salinity tolerance and is recorded in several areas around the world as an invasive plant in mangroves.

On 4 March we conducted an aerial census of waterbirds on Lake St Lucia. In all 21 000 birds were counted – half of which were waders.

Since mid-February the Mkhuze River had been flowing consistently into St Lucia and this was starting to influence the northern parts of the lake. There had not been much flow of the rivers entering False Bay.

Since the beginning of 2010 the Mfolozi had come down in flood twice – each time overtopping into the Link Canal and introducing sediment-laden water into St Lucia. The first of these floods (27 January 2010) was a 1 in a 5 year return period flood. The second, in early March 2010, was a bit smaller.

This low water level in the Narrows leaves the mangroves high and dry. They survived these conditions but a concern was the extent of kudu browsing of especially *Bruguiera gynmorrhiza*). This appeared to kill small trees and created a browse line of above 2.2 m. (Figure 95).

In Catalina Bay there were large beds of the bivalve stickbait (*Solen cylindraceus*).

North of Fanies Island conditions had been very severe as the water had been very shallow and salinity very high. Most of North Lake basin had no fish, almost no birds and the orange-coloured bloom of cyanobacteria persisted. Tewate Bay was the exception where groundwater seepage maintained an environment for about 100 hippos and some crocodiles.

April 2010:

The Mfolozi Mouth closed naturally on 24 April.

May 2010:

About 35 scientists gathered to exchange knowledge on the Mfolozi/Msunduzi Estuary.

Mfolozi was breached artificially on 14 May after flooding farms (Figure 96).

Back Channel brought in an estimated 8 million m^3 water.

Salinity: Hells Gate 56 ppt, Charters 4 ppt, Narrows 2 to 6 ppt.

Figure 94. The invasive alien shrub *Schinus terebinthifolius* or Brazilian pepper which, in places, is gaining a foothold in the dry mangrove swamps.

Figure 95. Mangrove trees with a browse-line at about 2.2. m where they were being browsed on by kudu.

Figure 96. Breaching the Mfolozi estuary mouth on the evening of 14 May 2010.

June 2010:

Orange cyanobacterial bloom in North Lake continued.

Flamingoes were abundant.

In North Lake the water has been a bright orange colour. This has been caused by a bloom of cyanobacteria (being monitored by Dave Muir (UKZN) and Guy Bate (NMMU)) which has been thriving at the high salinity. Then, when salinity dropped into the 60s, there was an eruption of copepods (*Apocyclops* sp) (Figure 97) which were found in large numbers (recorded by Renzo Perissinotto (UKZN)). These in turn were being fed on by flamingoes. Meyrick Bowker (UKZN) took the photograph below (Figure 98) in late May of a large group of flamingoes – a photograph count indicated that there were over 7000 flamingoes in this one group. These flamingoes are likely to be filter-feeding on the copepods.

Assuming that average mass of a flamingo is 3 kg, and that they eat 10% of their body mass each day (rough estimate for birds) then this group alone consumed 2200 kg per day (2.2 tonnes of tiny copepods per day).

Part of the reason why the copepods are able to reproduce in such large numbers is that the cold spell in mid-July last year killed most of the fish in the area – and so there were few fish predators.

July 2010:

Salinity ranged from almost fresh water to almost four times as salty as the sea.

August 2010:

Salinity: Hells Gate 85 ppt, Charters 46 ppt, Narrows 5 ppt.

The lake had divided into discrete compartments: Narrows, Makakatana, Catalina Bay, Dead Tree Bay, Fanies Island Channel and North Lake (Tewate, Sengwane, and False Bay were still connected). Selley's Lakes was dry.

Stuckenia pectinata was abundant in the Narrows and in Makakatana Bay (Figure 99).

A large shark (>2 m) was seen north of Mitchell Island.

Mkhuze River was not flowing.

Figure 97. The copepod, *Apocyclops*, that was occurring in large numbers in False Bay and was likely to be feeding on the cyanobacterial bloom. (Photo Renzo Perissinotto).

Figure 98. A flock of 7300 flamingoes near Hells Gates, likely to be feeding on the *Apocyclops* copepods. At present the food web is very simple in this extreme hypersaline area of the lake. (Photo Meyrick Bowker).

Figure 99. *Stuckenia pectinata* clumps growing in the Makakatana Bay (salinity 9 ppt).

October 2010:

Water level in the Narrows was the lowest in 5 years.

Excellent spring rains.

Stuckenia pectinata in Narrows was flourishing.

Hluhluwe dam was at 21% of capacity.

"Drought reins – it has been one of the driest years on record in parts of northern-KZN."

Hippos in St Lucia town were thirsty; they would drink from swimming pools.

November 2010:

The need for flood protection of the Link Canal was discussed at the Mouth Management Meeting of 22 November 2010. There could be channel-switching of the Mfolozi – then all the Mfolozi flows would come into St Lucia (and the sediments). (Figure 101).

A possible management intervention would be to block outlets at Honeymoon Bend and where the canal passes under the road. These actions will not prevent overtopping – but will stop the Link Canal from being the preferential flow route – and will hopefully fill the canal with sediment. There will still be sheet-flow northwards.

December 2010:

The Mkhuze River had come down in spate on several occasions.

The Hluhluwe dam was at 43% of capacity.

A very sharp and severe flood occurred in the Mpate River on 31 December.

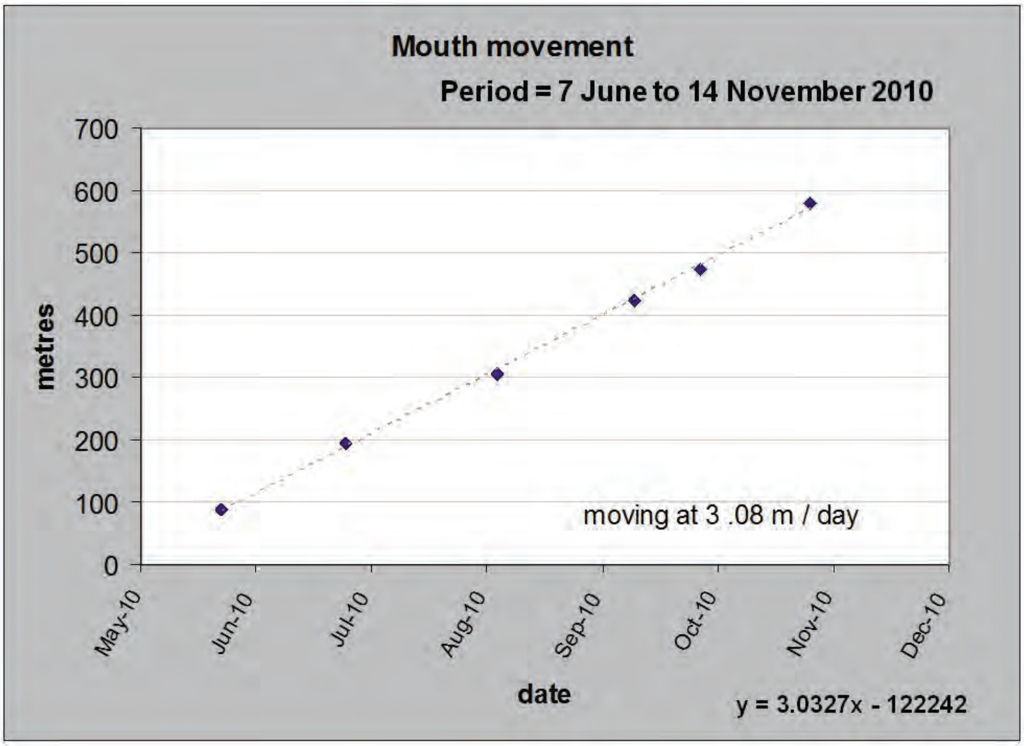

Figure 100. A graph tracking the northward movement of the Mfolozi Mouth (May to December 2010) where it moved on average 3.08 m a day.

Figure 101. The path for flood waters that overtop from the Mfolozi River during flood events. This water passes into Honeymoon Bend.

3.13 Timeline for 2011

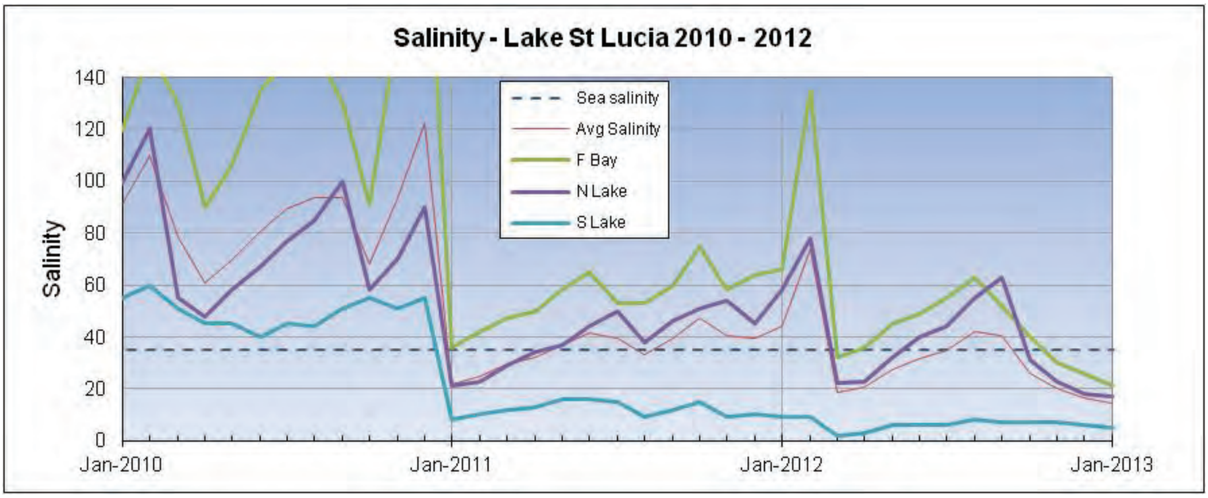

Figure 102. Salinity in South Lake was very low, but in North Lake it slowly increased as 2011 progressed. The gradient was due to an accumulation of salt in the northern parts of the system caused by a greater proportion of the water in the north evaporating than in the south.

January 2011:

Mpate River flooded on 31 December 2010 – overtopping the bridge.

The level of the Hluhluwe Dam is one of the best indicators of the amount of rain that has fallen. At the start of October it was 21% full. At the end of December it was 43% full and currently (24 January) it is 84% full.

The highest salinity that was in the system was 31 ppt measured at Listers Point. Everywhere in the lake salinity was lower than that of seawater.

February 2011:

An extremely high bird count. More than 30 000 birds were counted in St Lucia.

On the morning of 21 February the combination of rough seas and unusually high tides resulted in the sea overtopping the beach berm at St Lucia and seawater entering the estuary. While this was happening *Varuna* crabs, trapped in St Lucia were trying to walk upstream the inflowing water to enter the sea.

Catch cards from Charters Creek indicated good catches of grunter, yellow-fin bream, springer and perch. The size classes for grunter indicated that some of the larger fish would have recruited in 2007 when the mouth was open, but for the smaller individuals the recruitment happened since then. It is likely that this occurred via the Back Channel. This indicates that even a small connection to the sea is important to enable recruitment to take place.

March 2011:

Catch cards from Charters Creek indicated some good catches of grunter.

Good rains.

April 2011:

Very dense stands of the alien invasive plant *Flaveria bidentis* along the shoreline of False Bay Park. In all, this must line about 5 km of the 22 km shoreline of False Bay Park, forming a dense hedge of about 2 m high. It selectively grows on deposits of saline wind-blown lake sediments. (Figures 103 & 104).

The Mfolozi Mouth had been edging northwards. There was the possibility that it would erode into St Lucia Mouth later that year – effecting a connection between the Mfolozi, St Lucia and the sea. It was decided that the managers would not intervene.

May 2011:

The Mfolozi Mouth closed on the evening of 26-27 May. With the mouth closed, the water backed up to a level causing it to flow into the lake via the Back Channel. By 3 June this flow was at a rate of 1.1 cubic metres a second (almost 100 000 cubic metres per day). This had risen to about 2 cubic metres per second (200 000 cubic metres per day) by 11 June. This was good sediment-free water that was entering St Lucia. As flows in the Mfolozi were greater than the flows through the Back Channel, there was a backing up of water in the lower floodplain area, and at some point this flooded the fields of the sugarcane farmers.

Figure 103. Dense ‘hedge’ of the alien *Flaveria bidentis* near Sandy Point, False Bay.

Figure 104. Close-up of the *Flaveria bidentis* plant in flower. The yellow flowers in clusters and the red stems of the older plants are diagnostic.

June 2011:

White-breasted Cormorants and Caspian Terns were breeding in False Bay on a small island off Sandy Point. (Figure 105). The lake had large Mozambique Tilapia populations – a good food supply. There also seemed to be abundant prawns in South Lake and also of the fish *Hilsa keelee*. Both of these were a good source for the terns. The Mfolozi water was flowing into St Lucia via Back Channel

Figure 105. The White-breasted cormorant and Caspian tern breeding colony in False Bay. The count was approximately 165 cormorants and 150 terns.

The Great White Pelicans were breeding on a spit extending north from Lane Island. There were a few thousand birds at the nesting site – indicating a large number of nests, and already some chicks.

Bate, G. F., Whitfield, A.K. & Forbes, A.T. (Editors) (2011). A review of studies on the Mfolozi Estuary and associated floodplain, with emphasis on information required by management for future reconnection of the river to the St Lucia system. Water Research Commission Report No KV 255/10, Pretoria. This is a 300 page document published by the Water Research Commission and is the proceedings of the Mfolozi-Msunduzi Indaba held at St Lucia in May 2010.

July 2011:

It was decided that an additional outlet from the Back Channel should be excavated to increase the amount of water that could flow into St Lucia (Figure 106). This 40 m channel would also reduce some of the back-flooding that affects the sugar by allowing more water to drain through into St Lucia.

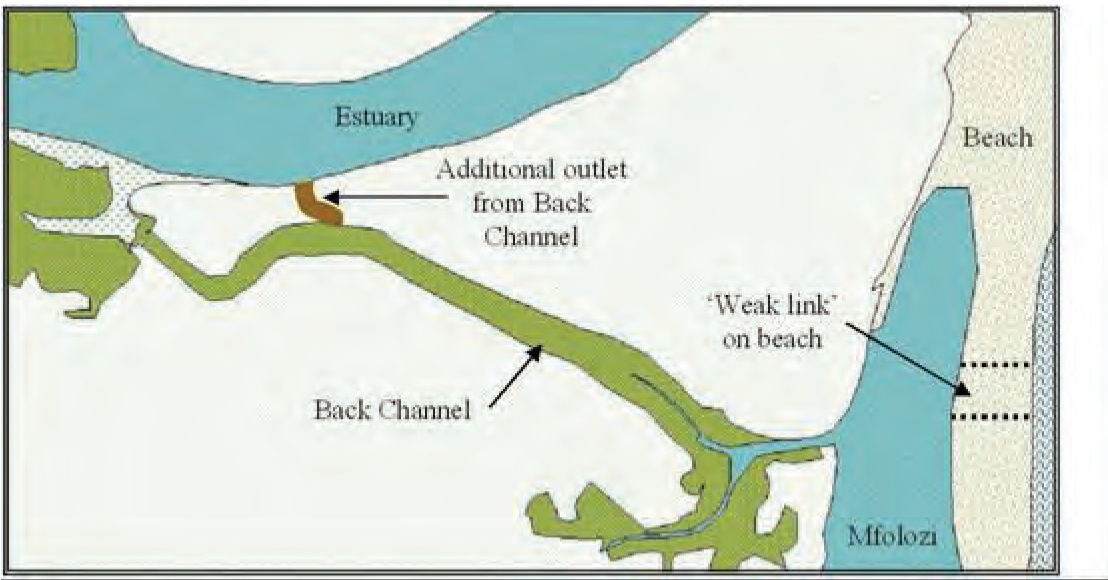

Figure 106: Map showing locality of proposed additional outlet from the Back Channel, and the 'weak link' (safety valve) on the beach.

The effort to open this second outlet to the Back Channel failed due to the heavy rain causing the 26-ton excavator to become bogged down in the wet silt deposit. This had to wait here for a few weeks until the area dried up (Figure 107).

Figure 107: The long-boom excavator stuck in the silt while working on the additional outlet for the Back Channel. Its tracks are not visible as they are completely under the mud.

Eventually it was decided to breach the Mfolozi Mouth to relieve the pressure on the sugar fields. This was done on Friday 22 July.

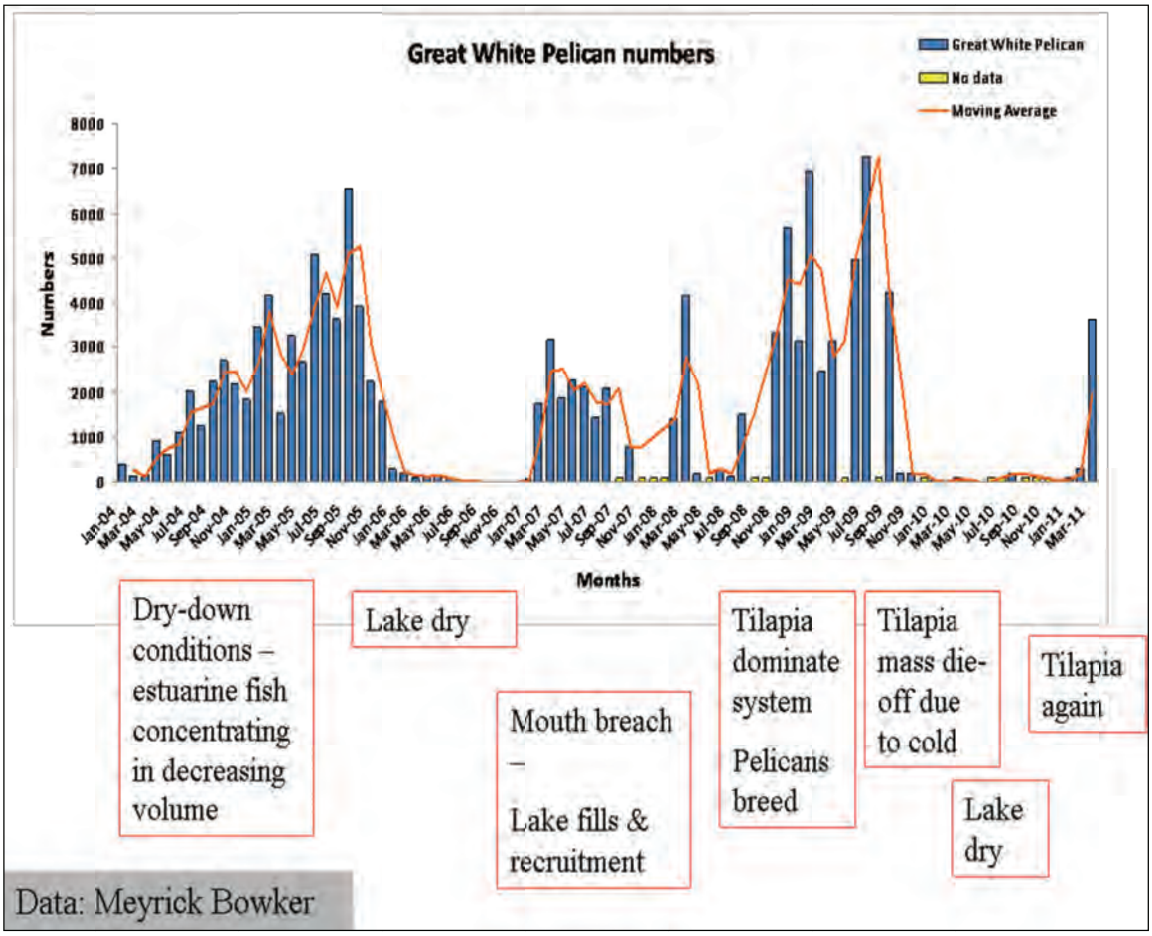

Figure 108. Part of a presentation given at the Marine Science Symposium, Grahamstown, showing how the pelican numbers track fish abundances.

With the low lake levels, the vegetation along the margins and beaches of St Lucia has been particularly rich and abundant. In addition, the salinity range was such that there were abundant beds of two of the submerged macrophytes (*Stuckenia pectinata* and *Ruppia cirrhosa*).

August 2011:

In August about 600 Great White Pelican chicks, some ready to fly, were seen on the sand spit north of Lane Island

Two papers published by Lawrie and Stretch (2011a & b) described how long term simulations of the water and salt balance were used to estimate the occurrence and persistence of water levels and salinities for different management scenarios (Figure 109). The management scenarios were:

Scenario 1: Separate Mfolozi and St Lucia Mouths and management to keep the St Lucia Mouth open virtually all the time (i.e. the strategy applied from 1956-2002).

Scenario 2: Separate Mfolozi and St Lucia Mouths, but no mouth manipulation. (i.e. the strategy applied since 2002).

Scenario 3: Combined Mfolozi and St Lucia Mouths with no active management of the inlet. (i.e. a “natural” state).

This was an important use of a model to consider different management scenarios.

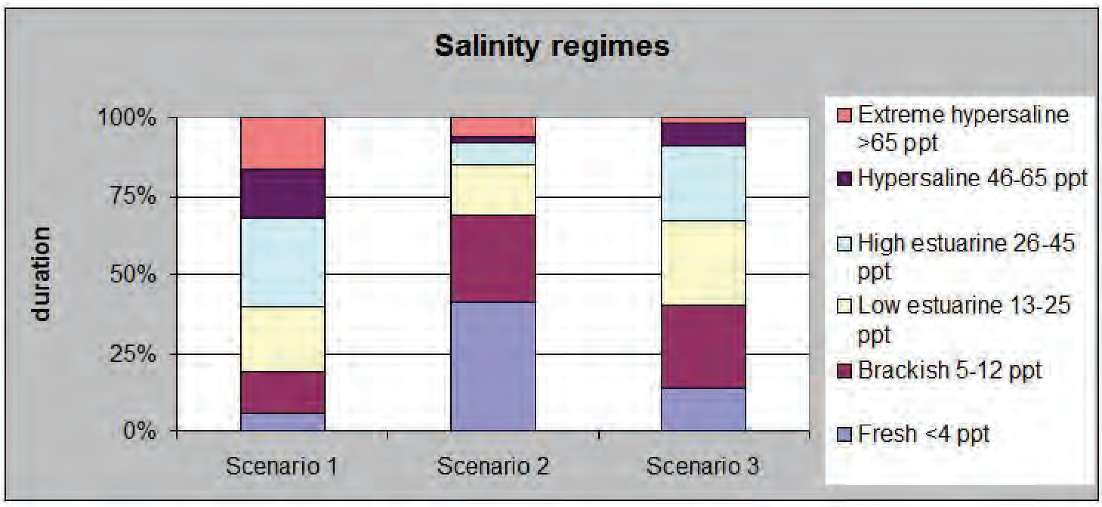

Figure 109. The chart indicates the different salinity regimes that would occur for each management scenario described by Lawrie and Stretch (2011a & b). The colours indicate the salinity states and the proportion of time that the lake would be in each of these states.

September 2011:

The Mfolozi Mouth closed on 4/5 September. An additional outlet to the Back Channel was excavated on 9 September and water has been flowing through it – and the original outlet – since then. This new channel was then widened to 12 m in width. The combined channels carried 2 to 3 m^3s^{-1} of water into St Lucia.

October 2011:

On 25 October there was a fish die-off in False Bay – mainly glassies (*Ambassis*). The cause of death was likely to have been osmotic stress (salinity 75 ppt) combined with sudden rise in temperature and wind which stirred up sediments causing anoxia.

On 24 October the Mfolozi Mouth was breached artificially, but closed again almost immediately.

The Great White Pelicans have had a particularly successful breeding season in St Lucia this year with well over 1000 chicks being fledged.

In the Msunduzi River, near CotCane, very green, eutrophic water was observed. This water was obviously enriched by agricultural runoff, and because there was reduced circulation due to the mouth closure, there was a concentration of algae.

November 2011:

A new species of gastrotrich was found; to be named *Halichaetonotus sanctaeluciae* sp. N. Mfolozi mouth was breached artificially on 9 November.

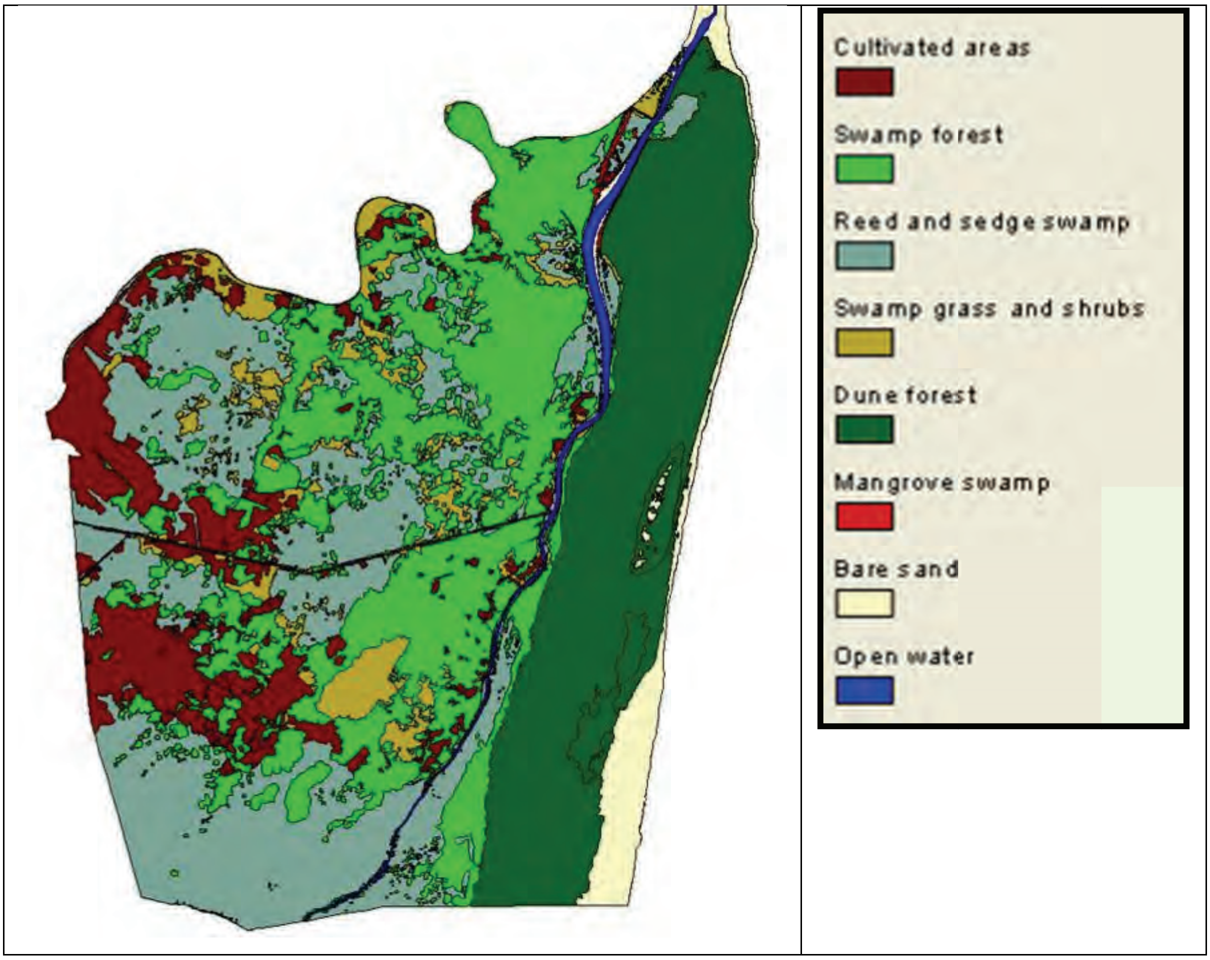

Figure 110. Vegetation map of the Lower Mfolozi Floodplain showing the distribution of the various vegetation types. (from Nondoda, Adams, Bate & Taylor 2011). There is a lot of concern about the extent of the cultivated areas.

December 2011:

Now that the last of the Great White Pelican chicks of the season has fledged, the researcher Meyrick Bowker estimates that over 2500 young were produced. This is the largest successful breeding in South Africa for several decades. It is important for long-lived birds that breed erratically to have a good recruitment like this every few years.

Management

In 2011 iSimangaliso publicised its strategy to let the Mfolozi River and Lake St Lucia join. This is a change in objectives which have, until now, focussed on keeping Mfolozi sediments out of St Lucia. Current thinking is that the risk of sediments to the health of the estuary has been overstated.

3.14 Timeline for 2012 – The drought breaks

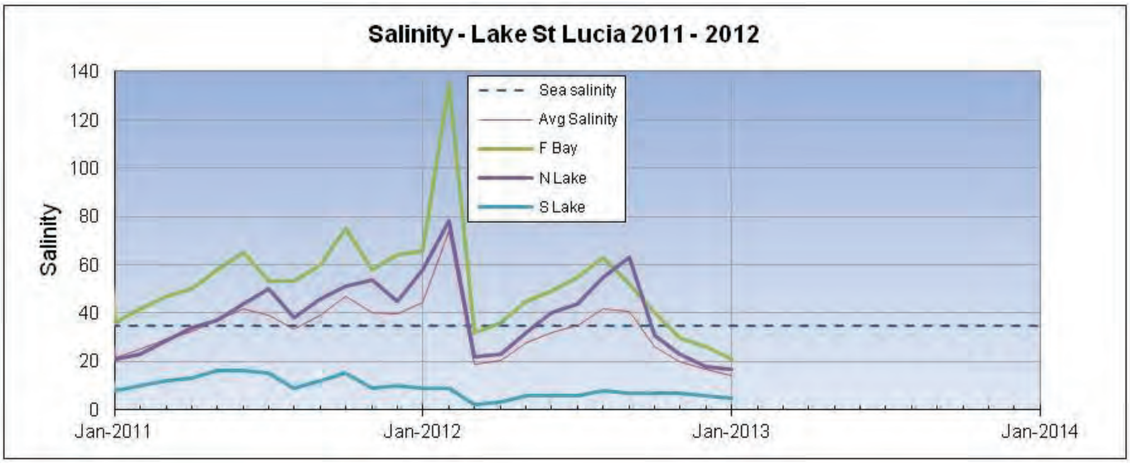

Figure 111 The drought ended in September 2012

January 2012:

Carrasco and Perissinotto (2012) described the biota found during the most severe of the salinity states – that ranging from 90 ppt to 130 ppt. There were only very few species present which formed a remarkably simple food web. In June 2009, a bloom of an orange-pigmented cyanobacterium (*Cyanothece* sp.) was recorded in False Bay and persisted for 18 months. This was fed on by a ciliate, which in turn was fed on by two copepods. It seems as if flamingoes then fed by filtering all of these from the water. The zooplankton disappeared at 130 ppt – but it is likely that they form resting spores that emerge whenever salinity is lower. (Figure 112).

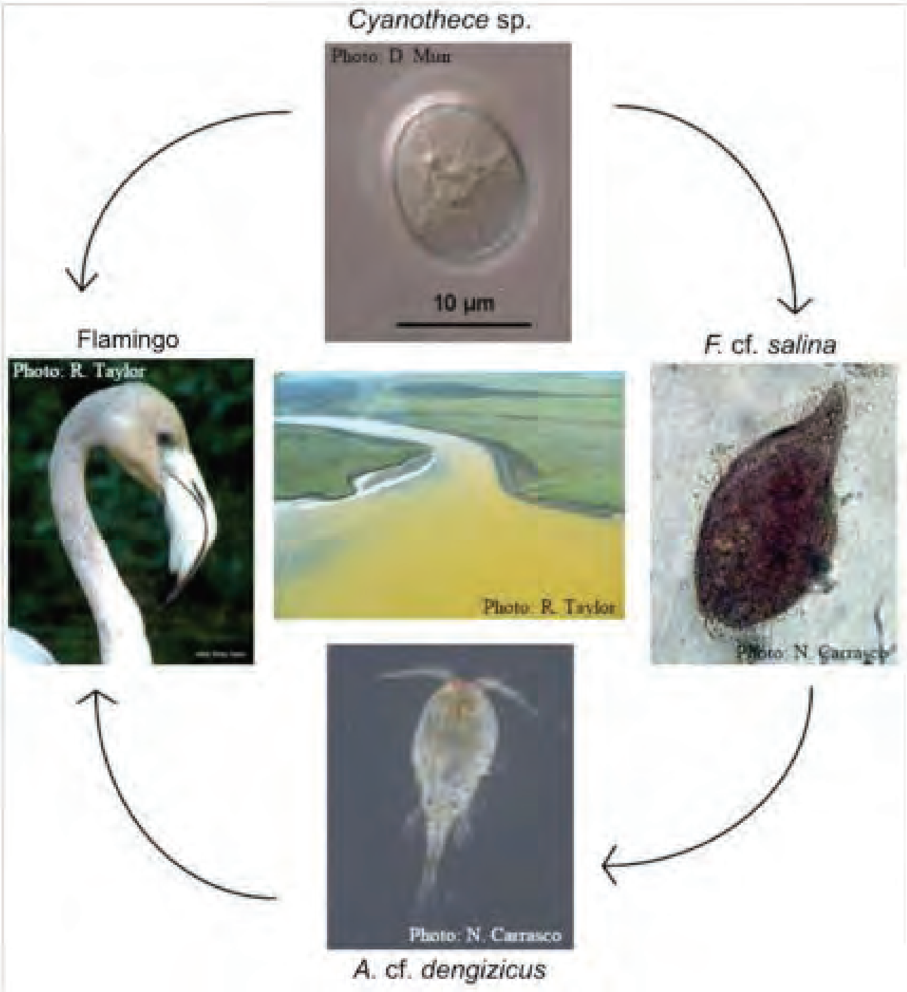

Figure 112. The simplified food chain that occurs at extreme high salinity in St Lucia.

Top picture – the cyanobacteria that blooms to give the water an orange colour (centre picture)

Right picture – the ciliate that feeds on the cyanobacteria.

Bottom picture – the copepod that feeds on the ciliate.

Left picture – the flamingo that feeds on all levels – especially on the copepods. (Illustration from Carrasco and Perissinotto, (2012).

February 2012:

The Mfolozi mouth was moving northwards at 2.9 m/day

Back Channel was allowing spring-tide water to enter St Lucia – enabling biotic recruitment.

The Mkhuze River was not flowing.

Salinity: Hells Gate 58 ppt, Charters 9 ppt, Narrows 3 ppt.

The St Lucia bird count was the highest since counts were initiated in 1976. This count was 44 000 birds. Of these 7000 were pelicans.

170 Caspian terns were noted breeding in False Bay.

March 2012:

Cyclone Irina passed close to the iSimangaliso Wetland Park in early March. At its closest it was about 125 km offshore off the Kosi-Sodwana area on 4 to 5 March. (see track of cyclone in Figure 113).

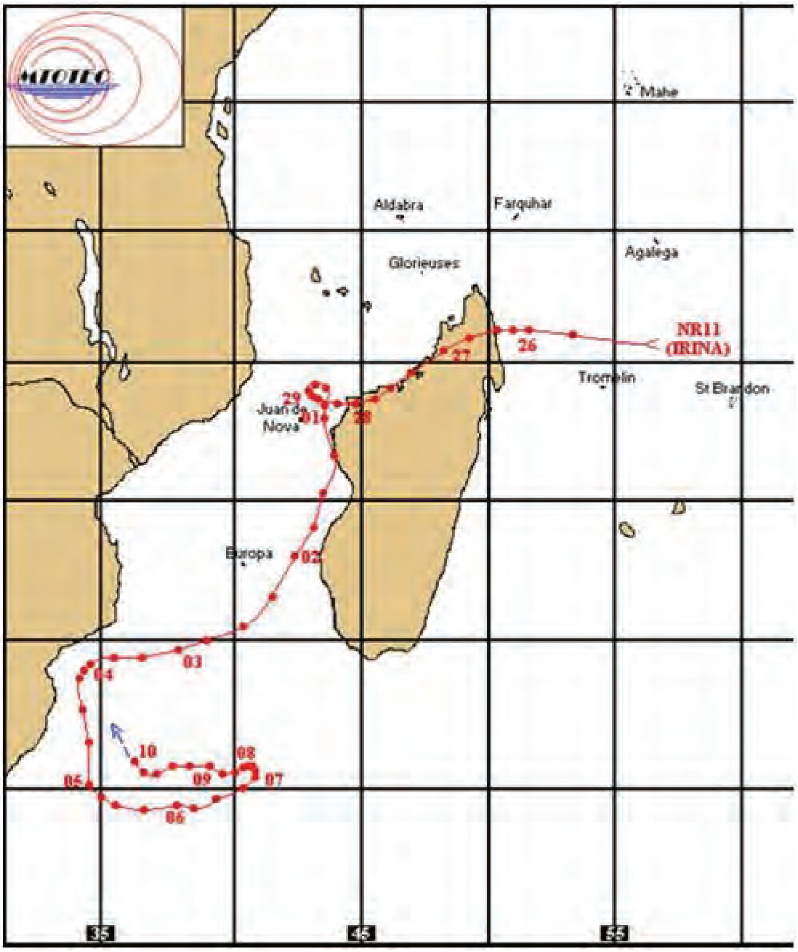

Figure 113. The path of Cyclone Irina in the end of February to early March 2012.

Cyclone Irina brought lots of rain to the coastal area, but not to the catchment (320 mm of rain fell at Charters Creek).

Seawater was overtopping the beach berm and flowing into St Lucia.

The inflowing water attracted fish which were trying to leave St Lucia. Many anglers were catching grunters, stumpies, snapper salmon and several other species of marine fish.

An effort was being made to link the Mfolozi to St Lucia via a ‘beach channel’, but the waves overtopped the berm to the south of the Mfolozi Mouth and caused it to create a new mouth some 300 m south of the existing one. See Figure 114:

Figure 114. The canal excavated to link St Lucia with the Mfolozi Estuary. It had not yet been joined to the Mfolozi Estuary.

In the Narrows and in the main lake there were numerous schools of small mullet (each fish about 10 cm in size). These mullet are evidence of a significant amount of recruitment that had been taking place via the Back Channel in recent months. When the Mfolozi mouth is open, seawater enters St Lucia via the Back Channel every high tide during the spring-tide period – and with it, enter fish and crustacean larvae.

The rainfall raised the water level of the lake by several centimetres and reduced salinity. It was currently less that 3 ppt off Charters Creek.

An unfortunate side-effect of the raised water levels was that the Caspian Tern nests were flooded and the colony abandoned

April 2012:

A woman was killed by a crocodile while fishing at the Mouth – on 3 April 2012.

May 2012

The Mfolozi Mouth closed naturally.

July 2012:

A man was bitten by hippo in St Lucia town. Hippos were grazing street verges and gardens. This was a regular feature of the town.

The removal of the sand plug between the Mfolozi River and St Lucia system occurred on the 6th July 2012 – establishing a connection via the Beach Channel.

September 2012:

The drought is over. Rivers are flowing. The marine connection is still very limited, via the excavated Beach Channel.

Management

In 2012 the new strategy for managing Lake St Lucia and the Estuary was implemented. This allows for the unhindered flow of Mfolozi water into St Lucia.

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