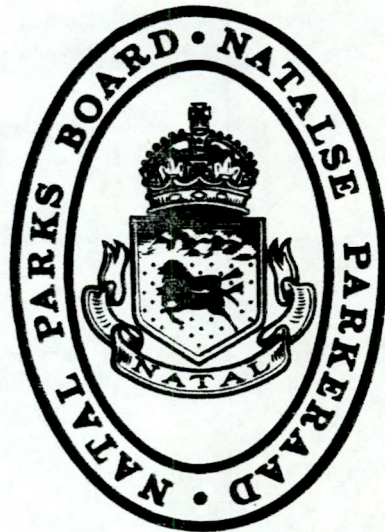


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**Author** TAYLOR R H

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CHARACTERISTICS

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ST LUCIA ESTUARY: THE AQUATIC ENVIRONMENT  
The Physical and Chemical Characteristics.

R.H. TAYLOR

1 INTRODUCTION

Knowledge of the physical and chemical environment is fundamental to the understanding of the biological processes which occur in an estuary. This paper attempts to give an overview of the environmental conditions in the St Lucia system.

Much of the information relating to the aquatic environment has been collected incidentally to projects relating to other aspects of the system and as a result there are several obvious gaps in our knowledge.

Excellent hydrological descriptions of the lake have been given by Kriel (1966) and by Hutchison (1976), otherwise the data are scattered through many reports and publications.

2 DIMENSIONS

2.1. Catchments

The St Lucia Estuary is fed by five main rivers and its local catchment. Figure 1 shows the extent of these catchments and their characteristics are shown in table 1.

Table 1

Catchment areas of Lake St Lucia.

catchment	*area km <sup>2</sup>	Mean annual runoff in million m <sup>3</sup> per year.
Mkuze	5380 - 6086	164 - 198
Hluhluwe	924 - 1010	20 - 28
Mzinene	700 - 808	22
Nyalazi	670 - 725	24
Mpate	65	11
Local catchment	1135	46
Total	8900 -	287 - 329

Relative importance of the Umfolozi:

Umfolozi	9918 - 11318	729
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## 2.2. The formation and shape of the estuary

An understanding of the geomorphology of the area is fundamental to the study of the St Lucia system. Review articles have been published by Hill (1969), Orme (1973), Orme (1974), Van Heerden (1976) and Hobday (1979). The system was formed within the past 25 000 years by the drowning of river valleys, by successive changes in the sea level and the filling up of the basin with sediments. The resultant system as we know it is north-south orientated with the old marine coastline forming its western shores, the drowned Mzinene, Hluhluwe and Nyalazi valleys forming False Bay, and the Mkuze swamps representing an infilled compartment of what was formerly part of the lake. The lake is divided into compartments by islands and connected to the sea by a 22 km long channel, the Narrows. The features of the lake are shown in figure 2.

## 2.3. Surface area

The water surface area varies according to lake level, and estimates of lake surface area at average water levels range from 32 500 ha (Begg, 1978) to 38 000 ha (Van Heerden, 1976). A relationship between lake level and surface area has been given by Kriel (1966) and by Hutchison (1974), but as the bathymetry of the lake has not been adequately plotted the accuracy of the relationship cannot be confirmed.

The length of the shoreline which averages approximately 347 km (Begg, 1978) also varies considerably with the rise and fall of the lake water level.

## 2.4. Bathymetry

The bathymetry of St Lucia Estuary was first measured by T.P. Dutton, a ranger in the Natal Parks Board. His measurements and those of the Department of Water Affairs were used to produce a bathymetric map for the St Lucia Commission Report (Kriel, 1966).

The Natal Provincial Administration (NPA) in 1971 surveyed the southern basin of the lake and plotted lake bed contours at 0.20 m intervals to a scale of 1 : 10 000.

Prior to the Narrows being dredged in 1967 to 1971, cross-sections of the channel were surveyed., Since then these, and cross-sections of the mouth have been regularly repeated by the surveyor appointed by the NPA Reclamation Unit.

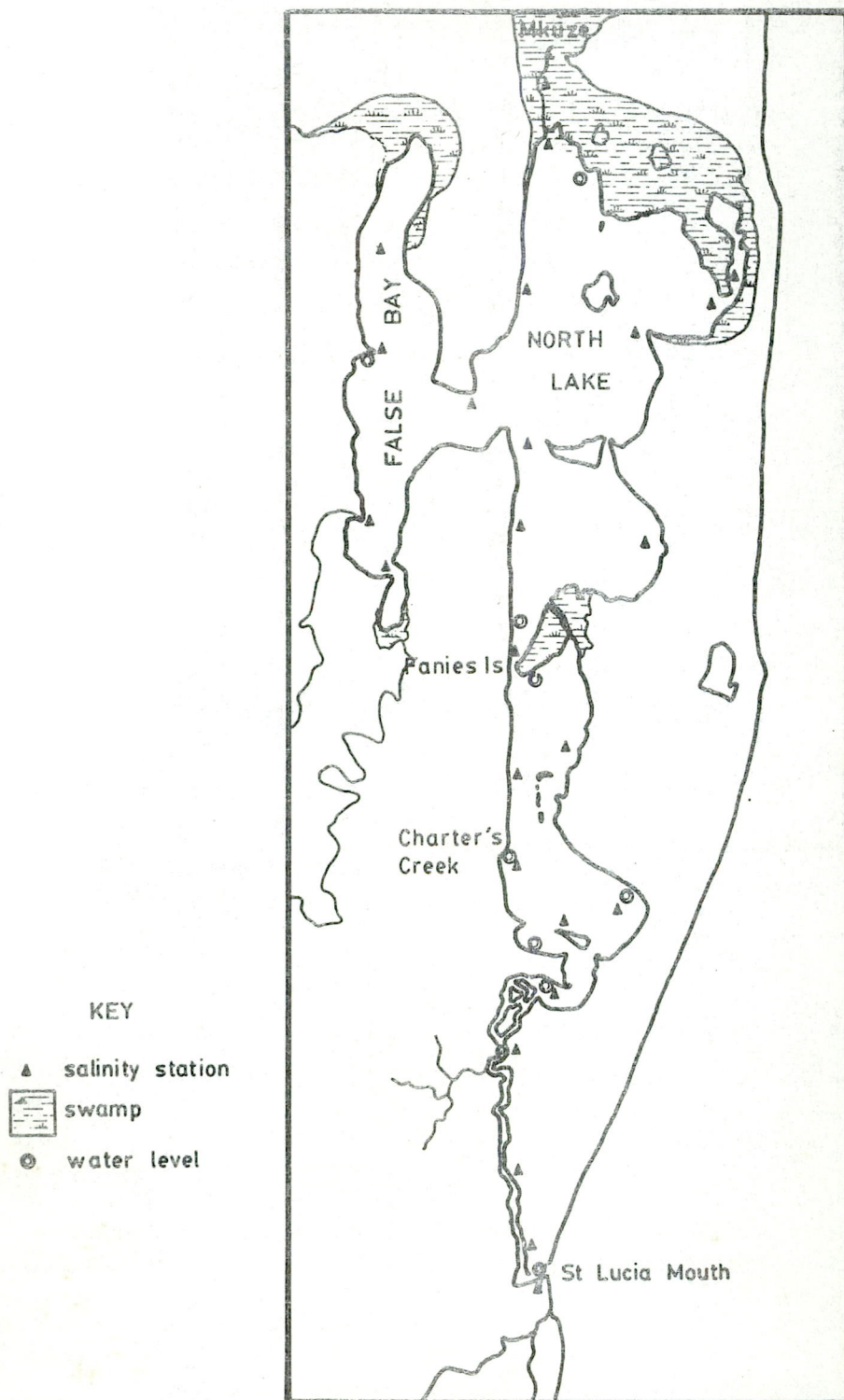


FIGURE 2: ST LUCIA ESTUARY

The Department of Water Affairs surveyed cross-sections of the lake in 1964 and in 1978 to determine the rates of sedimentation (Kriel, 1966; Dept. of Water Affairs, 1978). Unfortunately in only a few cases were the same cross-sections surveyed, and therefore the measurements from the different dates are not comparable. However these sections do give us valuable depth data.

The mean depth of the lake, depending on the water level ranges from 1 to 2 m with maximum depths of a little over 2.5.m occurring in the middle of Catalina Bay , off Dead Tree Bay and between Bird and Lane Islands.

#### 2.5. Lake levels

Lake water levels are measured continuously at several points around the lake by the NPA Reclamation Unit and by the Dept. of Water Affairs (figure 2). The water level recorders and their dates of installation are shown in table 2.

Table 2

#### Lake level recording

Station	Date installed
Mouth	1964
Esengeni	?
Potters Channel	?
Makakatana	1973
Old Jetty	1980
Charter's Creek	1958
Fanies south	1973
Fanies north	1973
Mkuze mouth	1973
Lister's Point	1958

Lake water levels vary considerably during long-term wet and dry cycles. A maximum weekly average water level of 0.97 m was recorded at Charter's Creek in 1976 and a minimum weekly average level of -0.43 m in 1970. (Levels relative to the Estuary Mean Level which is 0.25 m above Mean Sea Level).

Water levels are also affected considerably in the short term by winds which cause a seiche effect, piling the water up at the northern end of the lake when a south wind blows, and vice versa. Water levels at the Mkuze Mouth recorder

can rise by over 50 cm in a few hours when the wind changes from north to south.

The fluctuations in lake levels, both in the long and short-term cause changes in the amount of shallow water or freshly exposed habitat which is available (Whitfield & Cyrus, 1978) and is recognised by Berruti (1982) to be of great ecological importance.

### 2.6. Lake volume

The volume of water contained in St Lucia is obviously related to the lake bed contours and the water level. Hutchison (1974) has modelled this relationship, and gives figures for the volume of water for each lake cell for different lake levels.

## 3 WATER MOVEMENT AND SUBSTRATE

### 3.1. Sediments

Sediments enter the lake in the following forms: as waterborne silts carried in by all the main rivers, as silt brought in by the sea through the mouth, as wind-blown sands, or from the erosion of cliffs and islands within the system.

All the rivers entering the system have high concentrations of suspended clay and silt particles. With the exception of the Mkuze River, where the sediments are filtered out by the swampland, their loads are deposited when the river water mixes with the saline lake water. The salt weakens the electrostatic charges which keep the particles in suspension thus causing them to flocculate and settle.

When the St Lucia lake level is at or below mean sea level, sea sediments are brought into the system by incoming tides. If the Umfolozi River floods under these conditions an appreciable quantity of its sediments may also be carried into the system.

The Eastern Shores is composed largely of aeolian sands blown in from the sea. A certain amount of these sands must be deposited in the lake. Sediments in the system are also derived from the erosion of the cliffs of the Western Shores and from the islands.

A number of cores have been drilled in the lake to analyse the sediment deposition patterns. These cores show that the sediment infill in the system is up to 33.5 m in northern False Bay (Van Heerden, 1976).

Sediment loss from the system is in water moving from the lake to the sea. This process is accelerated by wind forming waves which cause turbulence resulting in the suspension of sediments. These sediments are then carried out to sea. Although Kriel (1966) has estimated that the siltation rate of the system is such that it will silt up completely in the next 115 to 240 years, it is possible that sediment loss from the system is higher than previously considered. Shallow estuaries reach an equilibrium state where sediment input is balanced by sediment loss. The critical factors controlling the equilibrium are the wind regime which forms the waves; the energy developed by the waves which determines the depth at which sediments can be resuspended; and the grain size of the sediments, the coarser the grain the greater the energy necessary for suspension. Whether such an equilibrium occurs at St Lucia has still to be determined. Care must be taken not to alter such an equilibrium if it should occur. This can be disrupted by increasing the sediment input, adjusting the depth by dredging or by introducing coarser sediments.

### 3.2. Lake substrate

The lake substrate varies from coarse grained sand to fine semi-liquid mud. No substrate analyses have been carried out, and figure 3 is the only substrate map available for the system. The substrate composition is very important for benthic organisms and rooted macrophytes, and this is one of our most critical gaps in the baseline information for the system.

### 3.3. Water circulation

The predominant winds are from the north to north-east and from the south-west. As the lake is orientated in more or less the same direction, so the wind-generated seiche effect is large. The winds shift large volumes of water between the north and south basins of the lake, and this water-movement forms the dominant currents in the system. Superimposed on these north-south movements is the flow of water from the upper reaches, where the rivers enter, towards the mouth; or at low lake levels, sea water entering the mouth and moving northwards. The Coriolis force, due to the rotation of the earth tends to deflect the currents to the left in the southern hemisphere resulting in an anti-clockwise circulation pattern.

These forces all combine to form the water circulation patterns of the lake. There are strong currents

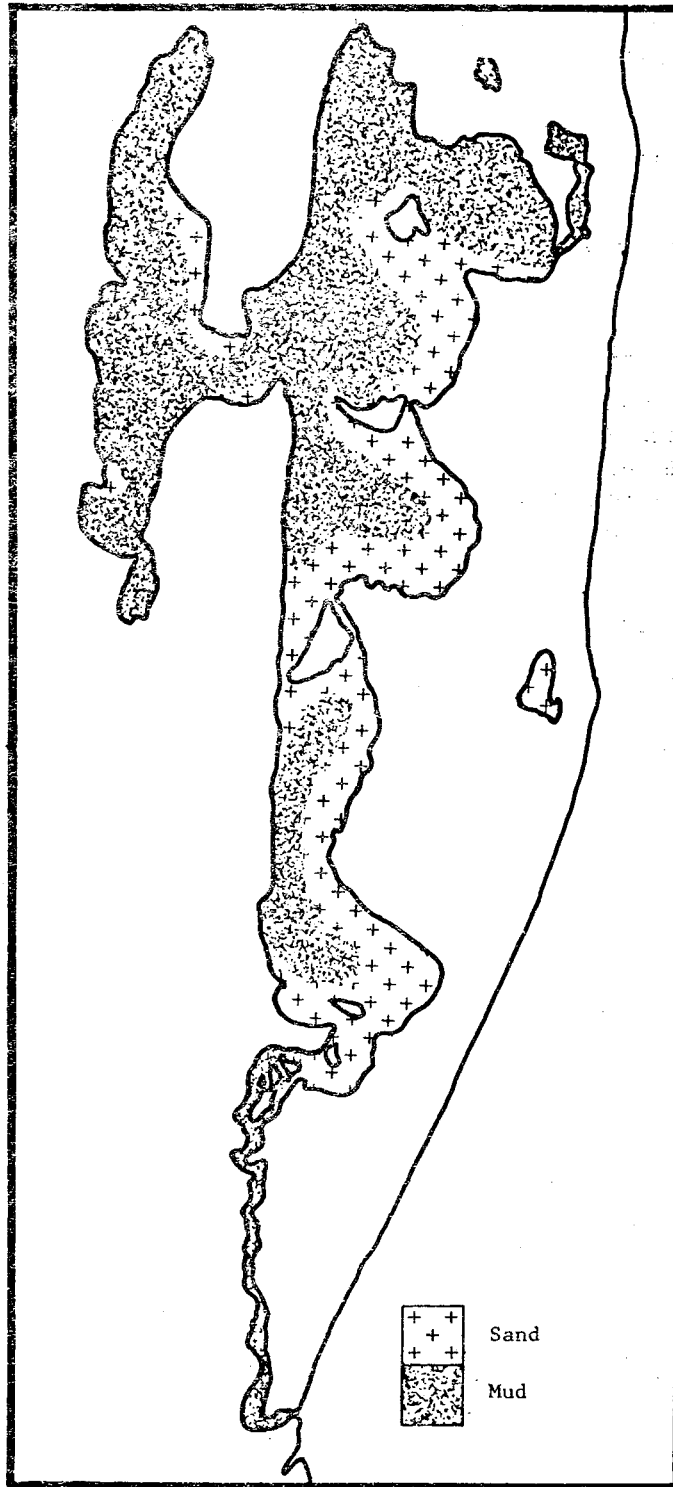


FIGURE 3: SUBSTRATE MAP

experienced in the channels at Fannies Island, and Orme (1973) has commented on the segmentization of the lake into several circular water bodies which would be due to the circular currents formed by the Coriolis force. Otherwise virtually nothing is known about the currents of the system - an aspect so fundamental to the understanding of salinity patterns, the movements of sediments and the movements of planktonic organisms.

### 3.4 Water turbidity

Lake St Lucia is an extremely turbid system. The turbidity of the water is related to wave action, water currents, the lake substrate and to the flocculation of sediments at the river mouths. Relatively little of the turbidity of the St Lucia system is due to phytoplankton.

The turbidity patterns are being measured by D. Cyrus who is studying turbidity effects on fish distribution.

Generally the eastern parts of the lake are less turbid than in the west as the substrate is sand as opposed to mud. The macrophyte beds tend to dampen any water movement causing a settling of sediments which results in extremely clear water.

### 3.5. Waves

Waves in the estuary tend to have a short wave-length as the water is so shallow. The amplitude of the waves is greatest where the distance to reach is the longest, and hence one expects the areas of greatest wave energy to be at the southerly to south-westerly or the north-easterly ends of the main water compartments.

As the water is shallow, much of the wave energy is expended on the substrate causing suspension of sediments and thorough mixing of the water body. This is important to the biota of the system as it causes the water to be well oxygenated, prevents the formation of any thermo- or haloclines and allows for a maximum amount of nutrient exchange between the water and the substrate. The continual stirring action of the waves on the substrate may also effect its colonisation by benthic organisms. No measurements of wave action or patterns have been made.

### 3.6. Tides

At the mouth of St Lucia the tidal range may be over 2 m

during spring tides, and is less than 0.3m during neaps. The whole of the Narrows is tidal, and a distinct, but small tidal fluctuation is recorded at the Potter's Channel water level recorder. Here the tidal delay is approximately 4 to 5 hours due to water resistance of the channel and the distance from the mouth.

### 3.7. The state of the mouth

The state of the mouth is monitored by the NPA Reclamation Unit. Sea sediments tend to be deposited in the mouth and for much of the time dredging is necessary to prevent it from closing. Formerly, when the St Lucia Estuary and the Umfolozi River had a common mouth, the force of water pushing down the Umfolozi would have maintained this link to the sea which is so vital for the migrations of marine life to and from the system.

Periods of closure of the mouth are given by Hutchison (1974).

## 4 TEMPERATURE, EVAPORATION AND SALINITY

### 4.1. Water temperature

Very little temperature data are available for the lake. Whitfield (1977) gives the highest temperature he recorded as 29°C and the lowest temperature as 17°C. We have no idea what the extreme maximum and minimum temperatures for the system are.

Due to the wave action no thermocline forms except in the sheltered macrophyte areas. Here extremely high localised temperatures may be experienced.

### 4.2. Evaporation

Evaporation is measured at various localities adjacent to the lake. This is done using "A" pans or "Symonds" pans. These measurements do not give a true relationship with the evaporation rates of water from the lake, as various factors such as water temperature, relative humidity, wind speed, wave action and salt content of the water cannot be duplicated in a small pan. Hutchison & Pitman (1973) have estimated evaporation losses of water from the lake to be 1380 mm per year.

### 4.3. Salinity

Water salinity is measured at 25 stations monthly. From these measurements average salinities for the main lake cells are calculated (Hutchison, 1974), and salt loads can be derived.

Under normal conditions a salinity gradient exists. Salinities range from virtually fresh water at the river mouths, in the north of the lake to 35ppt. at the mouth where there is an interchange of lake and sea water.

During extremely wet periods, the lake level will rise, and an abundance of fresh water will flow into the lake lowering salinities. Hypo-saline conditions may result, such as occurred in 1976 when salinities were well below 5ppt. throughout most of the lake.

Conversely, during drought periods, little fresh water enters the system, the lake level drops through water loss by evaporation and there is a net input of water into the system from the sea. As the evaporated water is replaced by sea water, so the salinity of the lake rises. When the average salinity of the lake rises above 35ppt., a reverse salinity gradient is established. Then the highest salinities are measured furthest away from the mouth and sea water entering the system actually dilutes the lake water. Under such hypersaline conditions salinities of 115ppt. have been recorded.

Under both hyper- and hyposaline conditions salinities in the Narrows remain relatively stable and close to that of sea water.

St Lucia, a shallow estuary, has a large surface area to volume ratio. Thus a relatively small water loss through evaporation has a large salt concentrating effect. Whereas a deeper water-body would be buffered against change, salinities in St Lucia can change rapidly. This creates a harsh unstable environment for the biota which have to have wide tolerance, or must be able to colonise rapidly when conditions are suitable.

## 5. WATER CHEMISTRY

### 5.1. Chemical analyses

Chemical analyses of the lake water have been done by Vogel (1972), Johnson (1977) and by the Department of Water Affairs regularly since 1973 (Unpublish data). Vogel used his data to show that the salts in the system were primarily derived from sea water and not from seepage from the land. Johnson's analyses were part of a study of the phytoplankton of the system. She showed that levels of nitrogen and

phosphorous were low and possibly limiting to algal growth. No interpretation of the data from the Department of Water Affairs has been attempted. Chemical analyses of the water of the rivers entering the lake was carried out by Archibald et. al. (1969) as part of a water quality survey carried out by the National Institute for Water Research.

#### 5.2. pH

The pH of the estuary water is usually alkaline with recorded values ranging from just below 7 to well above 9

#### 5.3. Oxygen concentrations

Although the anaerobic sediments of the lake exhibit a strong oxygen demand, the lake water is probably well oxygenated as the water is well mixed by the wave action.

Oxygen may be limited adjacent to the dredgers which stir up large quantities of anaerobic sediments. Conditions of oxygen deficiency may also occur in the macrophyte beds at night. During this period the plants are not producing oxygen by photosynthesis and there are large demands for oxygen from plant respiration and from decaying organic matter.

#### 5.4. Pollution

A survey was carried out by Oliff (1979) who analysed water, mud and animal tissue samples for heavy metals, and the mud and animal tissues for pesticides. His data revealed little to be concerned about, but provide excellent bench-mark information.

### 6 FURTHER RESEARCH NEEDS

#### 6.1. Water temperatures

The monitoring of water temperature is necessary to determine the maximum and minimum temperatures experienced in the system. In this shallow system temperatures can change rapidly over a wide range, and may well be limiting to certain species.

#### 6.2. Water circulation

Water circulation and currents need investigation. This is a most important data void.

#### 6.3. Substrate distribution

A detailed substrate map and substrate analyses are needed. The analyses should include grain size, clay mineral content

and organic content of the substrate.

#### 6.4. Wave action

The wave patterns and effects need to be investigated as waves are an important physical force in the estuary.

#### 6.5. Bathymetry

More accurate bathymetry information is needed to calculate areas of shallow water habitat at different water levels, and to obtain more accurate area and volume measurements of the system.

#### 6.6. Effects of dredging on water quality

The effects of dredging on water quality need to be determined. Dredging increases turbidity as well as creating an oxygen deficiency and stirring up sulphides and nitrites. For management purposes it is necessary to know the extent of this disturbance.

#### 6.7. Pollution monitoring

The levels of pesticides in the system need to be monitored at regular intervals to determine at an early stage any adverse effects, so that the source can be located and the cause of the problem treated.

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