NATIONAL PHYSICAL RESEARCH LABORATORY

THE CHEMICAL COMPOSITION OF LAKE ST LUCIA WATER IN FEBRUARY 1972

REPORT TO THE TECHNICAL COMMITTEE
ON LAKE ST LUCIA
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1. INTRODUCTION

At its meeting in December 1971 the Technical Committee requested that a survey be made of the chemical composition of the water in the lake with the object of determining the origin of the dissolved salts. Arrangements were made with Mr F. Joubert of St Lucia and on 29 February 1972 he collected a comprehensive set of samples from the lake and the rivers feeding it.

At the time the lake had received a large amount of fresh water from floods in January/February and from excessive rain over the area during February. Flood water from the rivers started reaching the lake in January and continued to flow in through February. In addition most of the lake area received over 400 mm of precipitation in February. This fresh water reduced the salinity of the lake from an average of about 55 ppt on 31 December 1971 to about 29 ppt on 29 February 1972, i.e. by a factor of nearly 2. A large amount of fresh water, admixed with saline lake water, also discharged from the lake into the sea during the period.

2. RESULTS

The 25 samples collected by Mr F. Joubert on 29 February are listed in Table 1. They consist of one sea water sample, 19 samples collected at those points in the lake where regular hydrometer readings are made, and 5 river water samples from points upstream from the lake. The collection sites are shown in fig. 1.

TABLE 1

SAMPLES COLLECTED ON 29 FEBRUARY 1972

	Sa No.	Locality	Area	Salinity*
1.	0253	Cape Vidal	Sea shore	
2.	S1516	NPB Jetty	Estuary	17.3
3.	S1517	Bridge		24.5
4.	S1496	Narrows		27.3
5.	S1497	Essengeni		27.3
6.	S1498	Potter's Channel	Southern Lake	29.3
7.	S1499	Michel Island		32.5
8.	S1500	Old Jetty		29.8
9.	S1501	Charter's Creek		30.0
10.	S1502	Dead Tree Bay		
11.	S1503	Fanies Island	Northern Lake	35.0
12.	S1504	Tewati		37.0
13.	S1505	Hell's Gates		24.5
14.	S1509	Sengwani		35.0
15.	S1510	Shelly's Lake area		31.2
16.	S1508	Lister Point	False Bay	23.4
17.	S1506	Nyalazi Ri mouth		10.5
18.	S1507	Hluhluwe Ri mouth		8.7
19.	S1513	Mkuzi Ri mouth		
20.	S1514	Mkuzi swamps		
21.	S1520	Mkuzi Ri, Thrings Store	Rivers	
22.	S1521	Mzineni Ri, bridge		
23.	S1522	Hluhluwe Ri, Main Rd		
24.	S1519	Nyalazi Ri, Main Rd		
25.	S1518	Umfolozi Ri, Monzi Br		

*Hydrometer measurements done by Mr F. Joubert and given in ppt.

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As soon as the samples were received at the CSIR they were submitted to the National Institute for Water Research for chemical analysis. In addition to the 8 major constituents, nitrate, phosphate and silicate, and 12 trace elements were determined. The results, kindly supplied by Dr W. Hattingh, NIWR, are listed in Table 2. The major constituents, expressed as milli-equivalents/liter, are graphically presented in fig. 2. This form of presentation has the advantage that it shows the composition of the original salts, i.e. it shows which cations and anions belong together. It further facilitates comparison of the relative composition of waters with widely differing salinity.

2.1 Salinity

The salinities derived from hydrometer readings by Mr Joubert (Table 1) compare very favourably with the more accurate determinations of the Total Dissolved Solids (TDS = TDVS) given in Table 2. The average of the two series of measurements differ by only 0.22 ppt. The largest deviation between two single measurements is 2.1 ppt. For salinities in the region of 35 ppt the accuracy of the hydrometer measurements can thus be considered as better than ± 50%.

The salinity of the Mkuzi River, which provides the main supply of run-off, was only 0.16 ppt and the average for five rivers was 0.22 ppt. It is probable that the salinity of this flood water is less than the average salinity for the rivers, but since it is mainly flood water that recharges the lake, these figures are considered to give a reasonably reliable value for the salt added to the lake from this source. We conclude, therefore, that the salt content of the run-off is only about 0.6% of that of sea water.

Only an insignificant amount of sea water in the lake would thus make a large contribution to the salinity: For half the salt in the lake to be of marine origin only 6 volumes of sea water need enter the lake for every 1000 volumes of river water. From these figures it seems probable that the run-off would only make a small contribution to the salt content of the lake.

A further source of salt in the lake is from ground water seepage on the eastern shores. To obtain an estimate of the salinity of this water, the total dissolved solids (TDS) of four samples were determined. In addition the TDS in one rain water sample was also measured. The results are given in Table 3. The average salinity of the four ground water samples is 0.225 ppt which is practically identical to the average value of 0.22 ppt for the five rivers. The ground water seepage can thus be considered together with the river water.

The result of 0.06 ppt for the rain water sample may be too high, since no special precautions were taken during collection.

T A B L E 3

SALINITY OF GROUND WATER AND RAIN WATER

Sample No.	Locality	Coll. date	T.D.S. mg/l
G522	Old Jetty	1:7:1972	210
G636	" "	29:2:1972	230
G521	Sengwane	1:7:1971	280
G639	"	31:3:1972	180
		Average:	225
P381	Charter's Creek rain water	Jan. 1972	60

2.2 Major Constituents

More information about the origin of the dissolved salts in the lake can be derived from a comparison of their relative composition. It can be seen in fig. 2 that the relative composition of the lake water salts is very similar to that of sea water (Sample 1) and dissimilar to the salts dissolved in the rivers. This becomes even more obvious when the gram-equivalent amounts are expressed as a percentage of the total number of gram-equivalents in the sample (fig. 3).

The main feature of the lake water is that it is a sodium chloride water: $(76.5 \pm .1)\%$ of the total gram-equivalents of salt is sodium chloride. This is practically identical with the value of 76.9% for the sea water sample (Sample 1) and much higher than the average of $(35 \pm 10)\%$ for the five river water samples.

The lake water contains more gram-equivalents of chlorine than of sodium, as does sea water. The amount of sodium chloride in the water is thus given by the amount of sodium present. The excess chlorine is mainly present as magnesium chloride. In the case of the river waters there is an excess of sodium with respect to chlorine indicating the presence of sodium bicarbonate or sodium sulphate. Here the amount of sodium chloride is determined by the number of gram-equivalents of chloride.

The slight relative deficiency of sodium chloride in the lake water (0.4%) with respect to the value of 76.9% for the sea water, can be used to calculate the proportion of salt contributed by the rivers. Using the figures given above, we obtain:

$$\frac{76.9 - 76.5}{76.9 - 35} = 1\%$$

This suggests that 1% of the salt in the lake is contributed by the rivers and 99% is derived from the sea. Due to the difference in salinity of the two sources, the mixing ratio of 99:1 would be brought about by mixing 6 parts of sea water with 10 parts of river water. The ratio was constant throughout the lake at the time the samples were collected.

The reasoning as presented above, can be misleading because the relative composition of the river water may change in the course of strong evaporation. Notably the bicarbonate will not increase indefinitely and calcium carbonate will tend to precipitate if the water volume is decreased appreciably. For this reason it is better to consider the ratios of certain of the ions. The ratios which would not normally change, are given in Table 4. It is again evident from these ratios that the composition of the lake water is very similar to that of the sea and markedly different from the river water. The slight deviations in the ratios of the lake water samples from those of sea water do not allow exact calculation of the salt contribution from the rivers. A maximum value can, however,

TABLE 4

ION RATIOS FOR COMPARISON OF LAKE WATER WITH SEA WATER AND RIVER WATER*

	Sample No.	Locality	$\frac{Na}{k}$	$\frac{Na}{Mg}$	$\frac{Na}{Cl}$	$\frac{Cl}{SO_4}$	$\frac{B}{SO_4}x10^{-3}$	$\frac{Sr}{Mg}x10^{-3}$
1.	0253	Cape Vidal	44.5	4.4	0.84	11.3	18	1.7
2.	S1516	NPB Jetty	42.0	4.3	0.84	11.4	17	1.9
3.	S1517	Bridge	51.1	4.1	0.85	9.5	15	1.8
4.	S1496	Narrows	47.6	4.1	0.83	12.0	17	1.7
5.	S1497	Essengeni	48.5	4.2	0.83	11.5	17	1.6
6.	S1498	Potter's Channel	47.6	4.1	0.83	10.7	16	1.6
7.	S1499	Mitchell Island	50.6	4.0	0.83	11.0	16	1.1
8.	S1500	Old Jetty	54.7	4.2	0.84	10.4	14	1.1
9.	S1501	Charters Creek	49.5	4.2	0.84	11.0	16	1.1
10.	S1502	Dead Tree Bay	50.9	4.2	0.84	10.5	16	0.9
11.	S1503	Fanies Island	50.9	4.1	0.83	11.1	16	1.4
12.	S1504	Tewati	47.3	4.2	0.83	13.1	19	1.4
13.	S1505	Hell's Gate	50.8	4.1	0.83	11.0	17	1.5
14.	S1509	Sengwane	47.4	4.0	0.83	10.8	16	1.5
15.	S1510	Shelly's Lake	47.2	4.0	0.82	12.3	19	1.5
16.	S1508	Lister Point	44.5	4.3	0.84	11.1	16	1.5
17.	S1506	Nyalazi Ri. mouth	47.4	4.1	0.84	9.7	15	1.5
18.	S1507	Hluhluwe Ri.mouth	42.0	4.1	0.83	11.2	17	1.6
19.	S1513	Mkuze Ri. mouth	46.0	3.9	0.86	12.9	32	2.3
20.	S1514	Mkuze Ri. upstr.	54.6	3.5	0.91	12.4	49	3.7
21.	S1520	Mkuze River	17.0	1.7	1.25	1.6	71	6.1
22.	S1521	Msinene River	34.0	5.2	2.60	2.1	130	9.1
23.	S1522	Hluhluwe River	15.0	2.3	1.24	8.0	150	5.5
24.	S1519	Nyalazi River	32.0	2.4	1.23	8.8	100	3.8
25.	S1518	Umfolosi River	17.0	2.0	1.55	7.9	180	10.0

*Ion contents are expressed in gram-equivalents per liter. Boron taken as two valent.

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be given: Based on the Na^+/Cl^- and Cl^-/SO_4^{++} ratios it is found that at least 98% of the salt is derived from the sea and less than 2% is contributed by the rivers.

The corresponding ratio of water masses required to produce this salt ratio is 23% sea water and 77% river water. Thus there are at least 3 parts of sea water for every 10 parts of river water in the lake and most probably this proportion is higher.

2.3 Minor Constituents

Here, too, there is a marked difference in the relative composition of sea water and that of the river waters, and the lake water corresponds closely to the former. Caution is, however, necessary when comparing minor constituents, since these can change in the course of aging by biological activity in the lake, by precipitation, or by differential adsorption on particulate matter.

Nevertheless, the average value of 9 ppm for silicon in the rivers contrasts markedly with 0.7 ppm for the sea water. The lake water samples have values much closer to the value of sea water than to that of the rivers. High values are encountered only in the mouths of the rivers. Similarly the iron content of the rivers (244 to 6300 ppm) is higher than that of sea water (178 ppm) and the lake water again corresponds more closely to the latter.

The relative proportions of boron and strontium are also significantly higher in the river waters than in the other samples. In Table 4 the ratio of the gram-equivalents of borate to sulphate and strontium to magnesium are listed. The average value of $B_4O_7^{=}/SO_4^{=}$ for the five river water samples is 126 x 10^{-3} as compared with 18 x 10^{-3} in sea water. In the lake the ratios are 14 to 19 x 10^{-3}, indicating similarity with sea water, but, in addition, some loss of borate. In the case of strontium the the average ratio Sr^{++}/Mg^{++} is 7 x 10^{-3} in the rivers and 1.7 x 10^{-3} in the sea. In the lake the ratios are 0.9 to 1.9 x 10^{-3}, also showing some loss of strontium.

It is remarkable that the samples collected at the months of the rivers (Samples 17 - 20) showed so little influence of run-off on the date of collection. The major constituents suggest that the water entering the lake at that stage was largely composed of old sea water draining from the swamps and of precipitation and that river water did not constitute a large proportion of the mixture. With respect to the minor constituents some influence of river water is already noticeable: The Mkuzi River mouth shows increased silicon, boron and strontium ratios, while the Nyalazi River and Hluhluwe River show the influence of run-off only in their silicon values. The high silicon concentration may, however, have been acquired in the swamps.

3. SUMMARY

(1) The salinity of the flood water feeding Lake St Lucia is about 0.2 ppt which is only 0.6% of that of sea water.

(2) The salinity of the ground water seepage from the Eastern Shores area is the same as that of the rivers.

(3) The hydrometer readings done monthly at Lake St Lucia, are accurate to within 5%.

(4) The relative composition of the major dissolved constituents in the lake water is very uniform and similar to that of sea water.

(5) The lake water can be classified as a sodium chloride water, while the rivers contain typical bicarbonate water.

(6) The ratios of Na^+ to K^+, Mg^{++} and Cl^- and the ratio of Cl^- to $SO_4^=$ in the lake water samples are all very similar to the ratios in sea water and different from those in the river waters.

(7) On the basis of the Na^+/Cl^- and $Cl^-/SO_4^=$ ratios it can be deduced that at least 98% of the salt in the lake is derived from the sea.

(8) Using the above figure it can be stated that at least 3 parts of sea water was present in the lake for every 10 parts of river water.

(9) The rivers contain more silicon and iron than the lake or the sea; the latter two being similar.

(10) The relative proportions of boron and strontium in the lake are similar to those in the sea and much lower than those in the rivers.

It is concluded that the chemical features of the water in Lake St Lucia on 29 February 1972 indicate that the salt in the lake is practically all derived from the sea and that the contribution from run-off and ground water seepage is insignificant. Any restriction in the amount of sea water entering the lake during periods when the water level is low, would thus tend to reduce the salinity of the lake water.

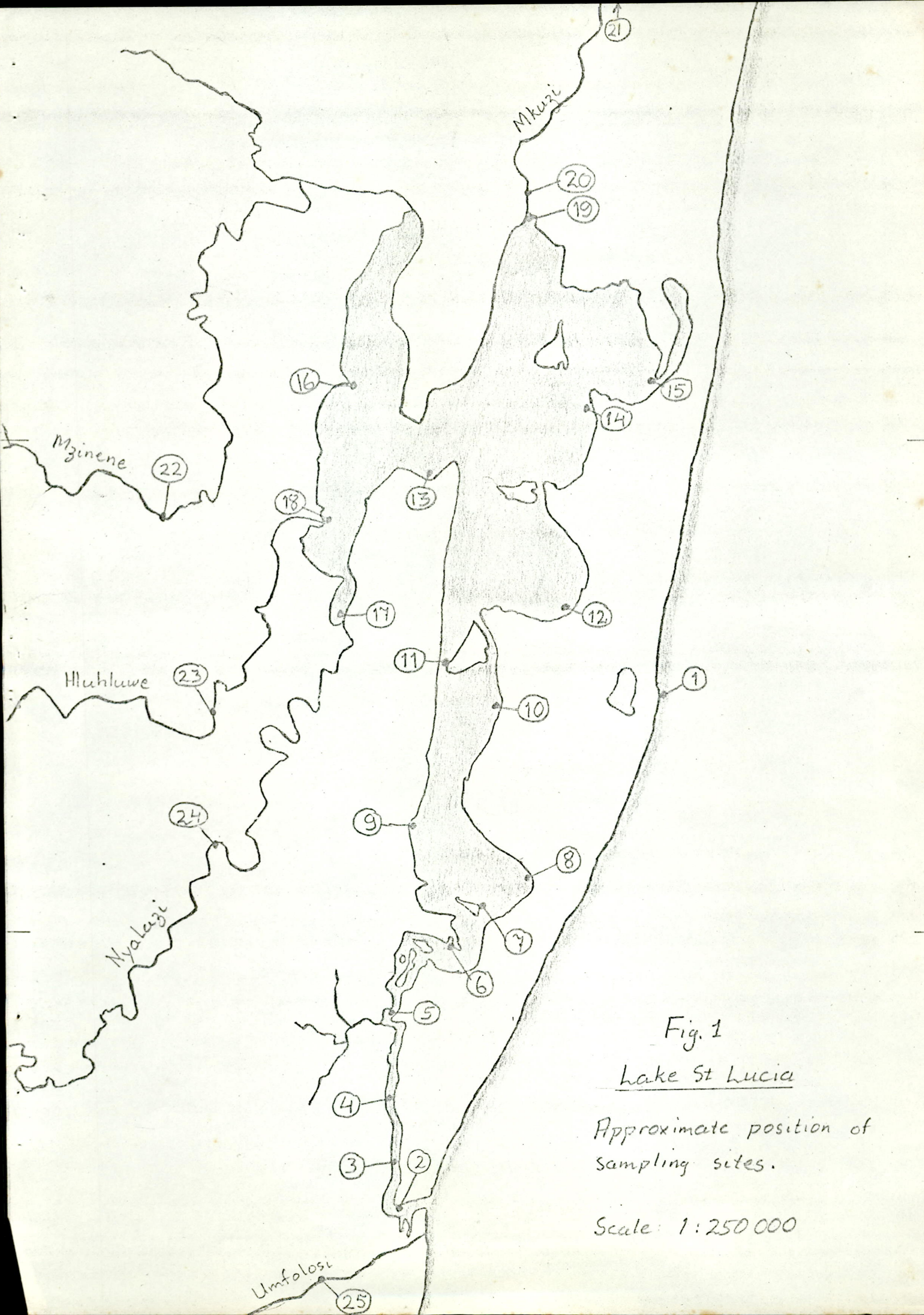

Fig. 1

Lake St Lucia

Approximate position of sampling sites.

Scale: 1:250 000