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ECOLOGICAL STUDIES OF THE ALGAE OF THE ST LUCIA SYSTEM

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INTRODUCTION

The St Lucia system, situated in northern Natal, is an extensive (328 km^2), but shallow estuary which experiences large and irregular salinity fluctuations. Although it has been the subject of considerable research (Heydorn, 1976), there have been few investigations of the algae. Cholnoky (1968) carried out a taxonomic study of the diatom flora of the system, and in 1977 Johnson reported on ecological studies of the phytoplankton population.

This paper reports on the composition and size of the phytoplankton population, the salinity tolerance of the resident species and the effects of nutrient levels on the population. Some proposals for future research are included.

THE PHYTOPLANKTON

Composition of the population

The population structure of the St Lucia phytoplankton is typically estuarine in spite of the unusually large salinity fluctuations experienced by the system. Euryhaline marine species, i.e. species with their centre of origin in marine waters, but common in estuaries due to their ability to tolerate a wide range of salinities, are common and widespread throughout the system. True estuarine and brackish water species, e.g. the diatom *Pleurosigma delicatulum* are also present and may dominate the population at times, while freshwater forms are rare, since they are unable to withstand even small salinity increases. (Table 1).

During periods of low rainfall when the water level in the system drops to below sea level, seawater flows into the system, carrying with it marine algae. The diatoms *Rhizosolenia setigera* and *R. stolterfothii* formed large populations in the northern regions of the system during 1974 after being carried into the system by seawater inflow (Table 2). The maintenance of a permanent connection with the sea is therefore of importance to the phytoplankton community.

TABLE 1: A list of the common species of phytoplankton of the St Lucia system categorised into marine, freshwater, brackish and estuarine species (after Cholnoky, 1968; Cupp, 1943; Giffen, 1963; Hendey, 1937; Hustedt, 1959; Peragallo, 1908).

MARINE SPECIES

Diatoms:

Actinoptychus splendens (Shabd) Ralfs
Amphipleura rutilans (Trent.) Cleve
Amphiprora pulchra Bailey
Asterionella japonica Cleve
Biddulphia mobiliensis Grunow
Chaetoceros lorenzianus Grunow
Coscinodiscus excentricus Ehrenburg
C. granii Gough
C. oculus-iridus Ehrenburg
Diploneis smithii (Brèb.) Cleve
Fragilaria luciae Cholnoky
Grammatophora oceanica (Ehrenburg) Grunow
Melosira nummuloides (Dillw.) C.A. Agardh.
Nitzschia acuminata (W. Smith) Grunow)
N. incrustans Grunow
N. longissima (Brèb.) Ralfs
N. lorenziana Grunow
Rhizosolenia setigera Brightwell
R. stolterfothii Peragallo
Thalassionema nitzschioides Grunow

Haptophyceae:

Halopappus? *adriaticus*

Chrysophyceae:

Dictyocha fibula Ehrenburg

FRESHWATER SPECIES

Diatoms:

Acnanthes minutissima Kützing
Fragilaria crotonensis Kitton
Synedra ulna (Nitzsch.) Ehrenburg

Chlorophyceae:

Gonium sp.
Pediastrum sp.
Cosmarium sp.

BRACKISH WATER SPECIES

Diatoms:

Chaetoceros subtilis Cleve
Melosira dubia Kutzing

Cyanophyceae:

Chroococcus sp.

ESTUARINE SPECIES

Diatoms:

Nitzschia aerophila Hustedt
Pleurosigma delicatulum W. Smith
P. strigosum W. Smith

Cyanophyceae:

Synechococcus bacillaris Butch.
S. leopoldiensis (Racib.) Komarek.

Chlorophyceae:

Nannochloris atomus Butch.

Population size

The only estimates of population size are those of Johnson (1977) who calculated cell density and volume during 1973 to 1976 (Tables 2&3). These figures indicate that in 1973 and 1974 the largest populations occurred in False Bay and North Lake, although these regions had the highest salinity levels. Volumes decreased in South Lake and were lowest in the Channel (Table 3; Fig. 1.). In 1975, however, when the salinity was considerably lower, the phytoplankton density in False Bay was much lower than in the two previous years (Fig. 3). Unfortunately data were not available for the rest of the system during this period.

TABLE 2a Population sizes (cells l^{-1}) and distribution of Rhizosolenia setigera in the St Lucia system between February 1973 and December 1975.

Date	Channel	South Lake	North Lake	False Bay
1/6/73	0,15 x 10^3			
3/74	1,5 x 10^3			
9/74	0,05 x 10^3			
10/74		96,5 x 10^3	115 x 10^3	
11/74		0,1 x 10^3		
12/74				1 x 10^3
1/75				0,53 x 10^3

TABLE 2b Population sizes (cells l^{-1}) and distribution of Rhizosolenia stolterfothii in the St Lucia system between February 1973 and December 1975.

Date	Channel	South Lake	North Lake	False Bay
10/74		0,4 x 10^3	9, 6 x 10^3	
11/74	8,2 x 10^3	133 x 10^3	4, 3 x 10^3	
12/74			2,15 x 10^3	
2/75				184,5 x 10^3

Salinity tolerance

Cholnoky (1968) noted that the number of diatom species dropped from the coast (77) to False Bay (57) since fewer and fewer species are able to tolerate wider and wider amplitudes of salinity change.

TABLE 3: Phytoplankton volumes (μ^3 ml^{-1} $month^{-1}$) in the four compartments of the St Lucia system.

	1973	1974	1975
Channel	112299	412265	-
South Lake	1379205	1360402	-
North Lake	4407983	3172961	-
False Bay	4021240	3740084	492590

From field records collected between 1973 and 1974 it was clear that salinity was a major factor influencing the distribution and frequency of occurrence of individual species. This was particularly significant in the marine forms which capitalise on favourable periods to colonize the estuary. Other species, however, were present over the entire salinity range recorded during this period (10 to 50 ppt.). (Table 4).

The establishment of upper and lower tolerance limits by the study of natural populations is, howerver, complicated by the number of other environmental factors which influence population size, e.g. temperature and predation. In addition, it is difficult to determine whether populations collected after a rapid salinity decrease are actively growing or merely "relic" populations. Thus in order to determine the maximum possible salinity range of some of the more tolerant species present in the system, three common species (*Pleurosigma delicatulum*, *Nitzschia longissima* and *Amphipleura rutilans*) were isolated and cultured in different salinities in the laboratory. For all three of these species, growth took place in salinities of between 10 and 60ppt. (Fig. 2).

Nutrient limitation

One of the features of the results from the general survey in 1973 and 1974 was that the largest population, and consequently probably the greatest productivity, occurred in the northern parts of the system which experienced the greatest fluctuations in salinity. However, as discussed above, whilst salinity is undoubtedly a factor controlling the composition of the phytoplankton, it may not be the major factor determing the size of the populations as

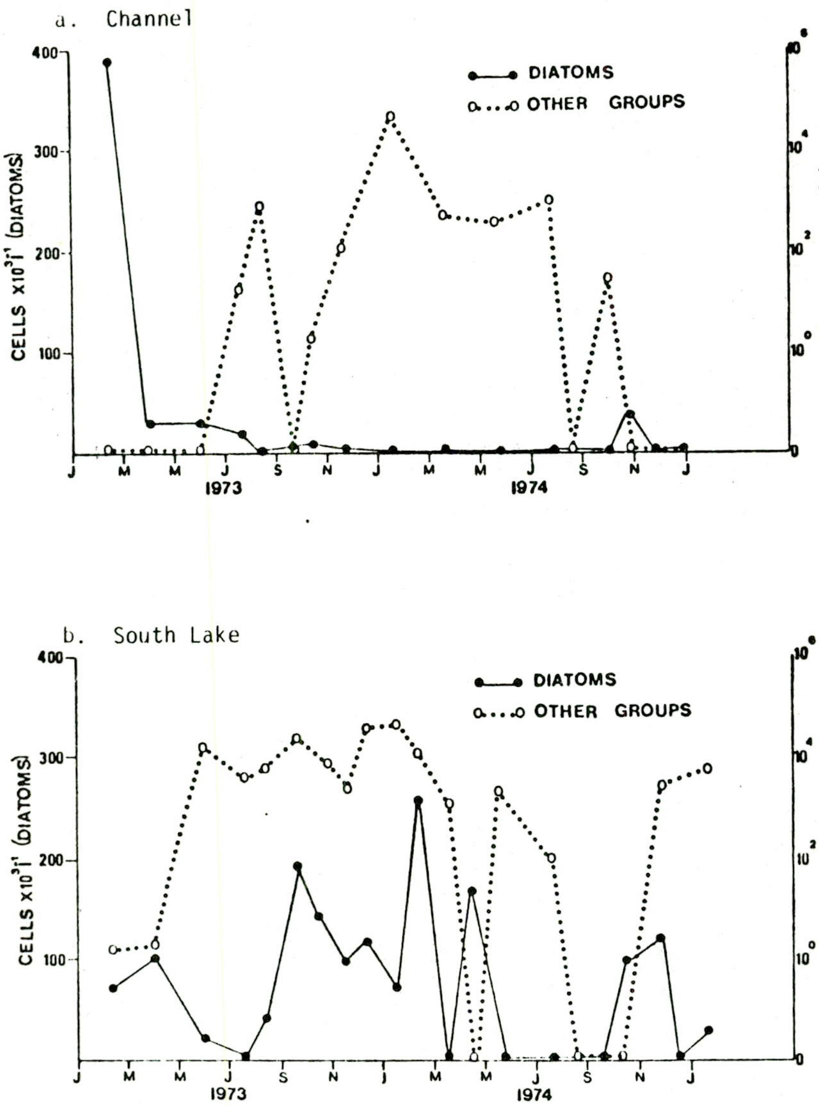
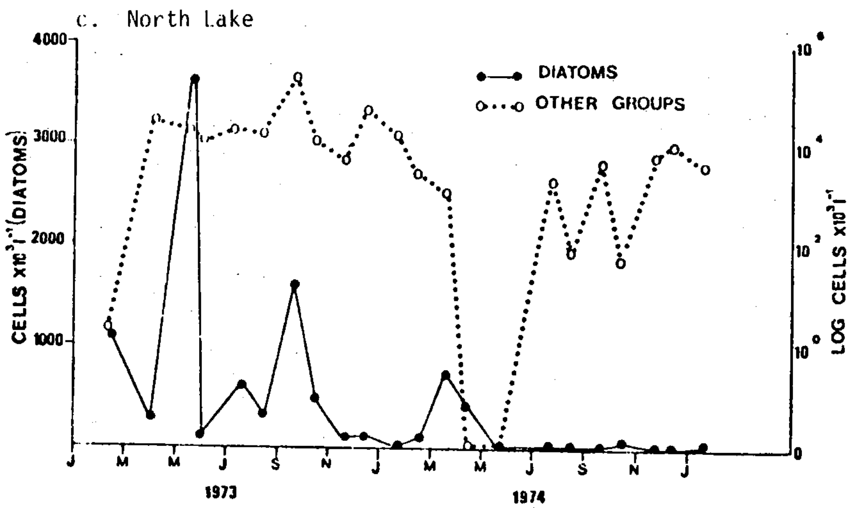


Figure 1. Numbers of diatoms and other groups (mean cell no. x 10^3 ℓ^{-1}) in the four compartments of the St. Lucia system during 1973 and 1974.



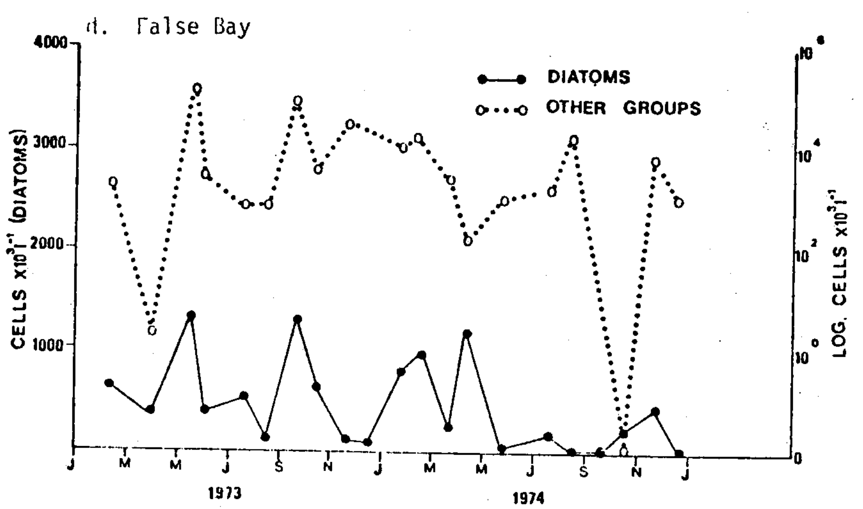


Figure 1. (continued).

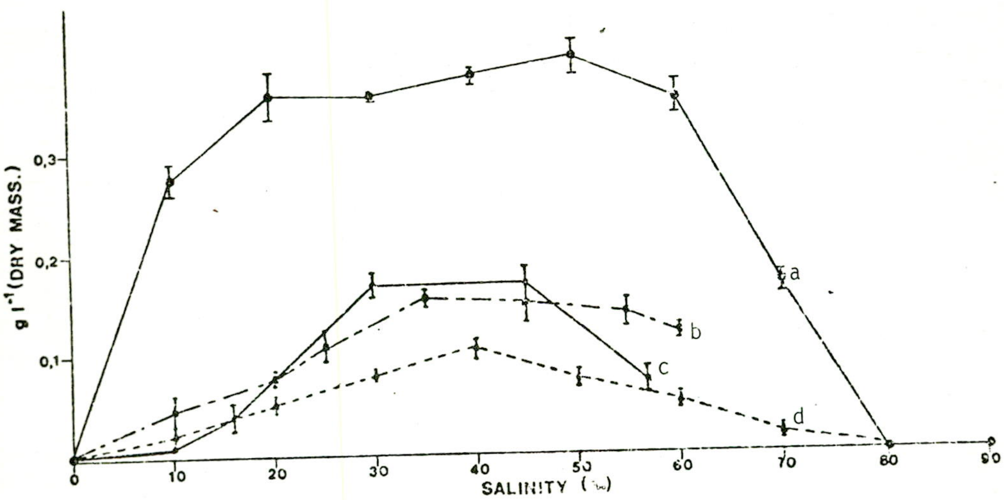
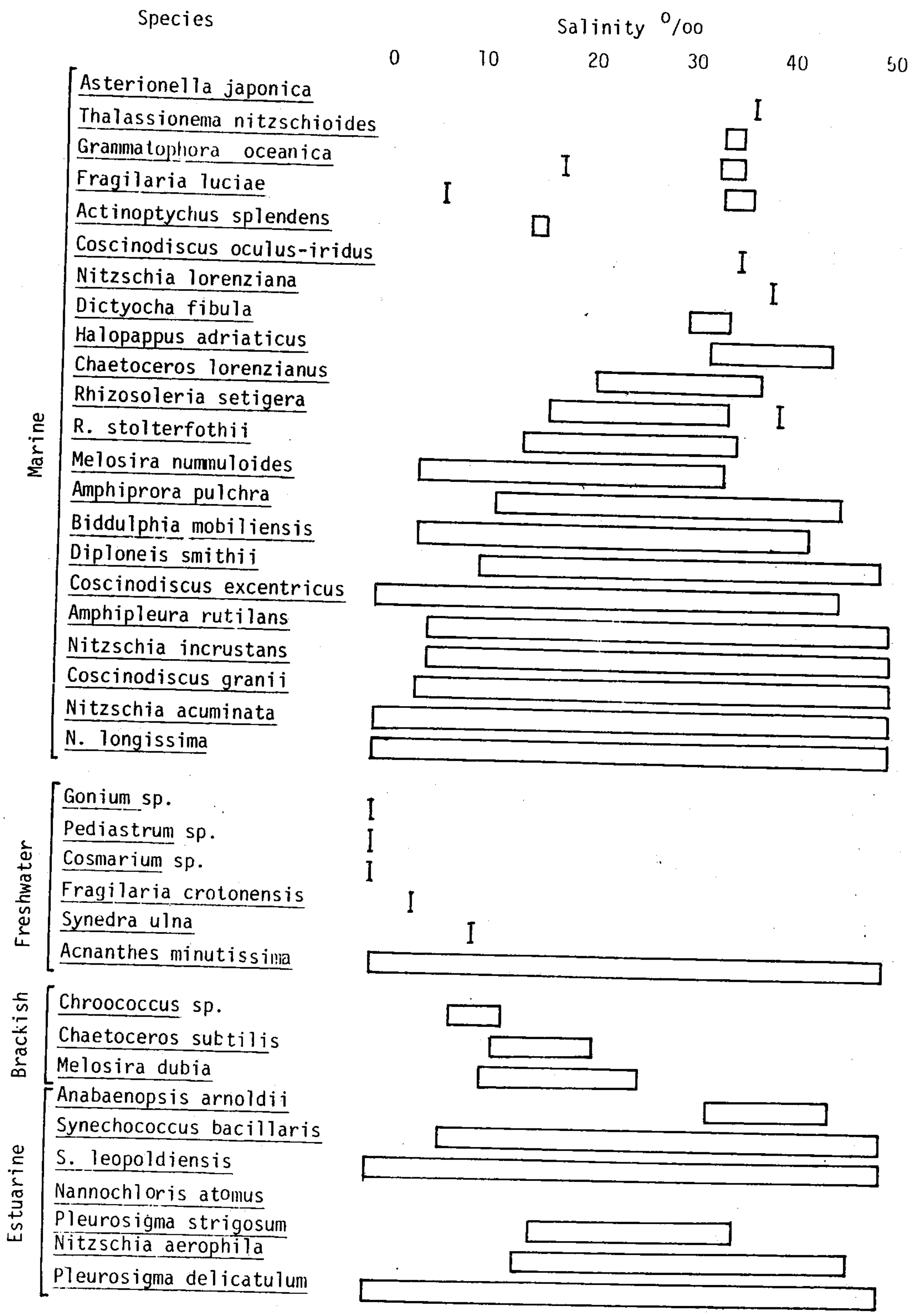


Figure 2. Salinity tolerance curves of a) Enteromorpha intestinalis, b) Pleurosigma delicatulum, c) Nitzschia longissima and d) Amphipleura rutilans. (Vertical bars represent one standard error of the mean).

6: ALGAE

TABLE 4: Recorded salinity ranges of the more common phytoplankton species of the St. Lucia system (Johnson 1977).



a number of resident species were tolerant of the range of salinities experienced during the study period.

Among other factors that are important in controlling the population size of phytoplankton is nutrient supply. Since False Bay and North Lakes between them receive 81% of the total freshwater inflow to the system (Hutchison, 1976) and since they supported the largest populations, it seemed possible that this high productivity was a response to nutrient enrichment by inflowing waters.

Information regarding the nutrient status of St Lucia is limited, the only two studies being those of Vogel (1972) and National Institute for Water Research (1969) which concentrated on the tributaries. Thus it appeared that a survey of nutrient availability, using both chemical analyses and algal bioassay methods, might be informative with regard to phytoplankton population changes. This investigation was carried out during 1975 (Johnson, 1977) a period characterized by lower salinites and lower populations than 1973 or 1974 (Fig. 3; Table 3). Salinity was maintained at approximately 10 ppt for eight months, during which time phytoplankton populations were apparently unable to re-establish themselves at the levels they had attained when salinity was higher (Table 3). In fact, total phytoplankton volume was even smaller than that reported from oligotrophic Midmar Dam by Twinch (1976). This implies that low salinities are detrimental to the phytoplankton populations of the system.

Another explanation might be that these small populations reflected the low nutrient status of the False Bay water during this period. The results of the the chemical analysis showed that the levels of nitrogen (NO_3N) and phosphorus (SRP), which are commonly implicated as growth rate limiting nutrients for algae, were low (Fig. 3). This was supported by the algal bioassay results, which indicated that both N and P were limiting to algal growth throughout 1975, P being the primary growth rate limiting nutrient from January to July, after which the two became equally limiting (Table 5). This trend appeared to result from the low levels of SRP in the inflowing fresh water. During the first half of the year, when most inflow took place, SRP levels were low, whereas in the second part of the year, when there was little inflow, SRP concentration increased (Fig. 3)

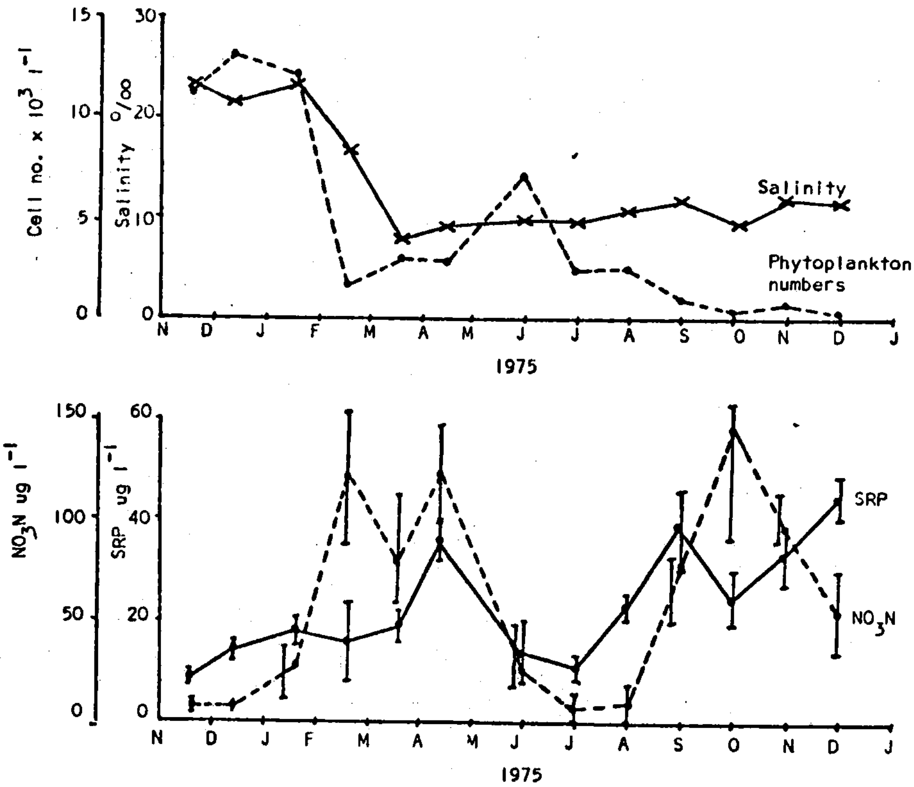


Figure 3. False Bay 1975: Salinity, Phytoplankton numbers, SRP and NO_3N levels.
(Vertical bars represent one standard error of the mean).

TABLE 5. Growth Response of Dunaliella tertiolecta in False Bay, Water Samples (1975).

Treatment \ Month	Jan.	Feb.	Mar.	Apr.	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Control mg ℓ - after 14 days	41,4	4,5	4,5	6,6	22,4	16,6	9,3	21,4	11,3	14,9	9,8
-0,05mgP ℓ $^{-1}$	53,1*	46,7*	17,3*	23,9*	47,6*	31*	20,3	32,4	25,9	28,4	13,8
-1,0mgN ℓ $^{-1}$	39,8	3,7	13,5	4,3	22,2	11,2	7,5	19,8	8,8	16,8	9,1
-0,05mgP ℓ $^{-1}$ and -1,0mgN ℓ $^{-1}$	114,5*	56,3*	86,4*	88,2*	95,9*	75,5*	81,5*	87,9*	55,6*	72,3*	68*
Limiting nutrient	P	P	P	P	P	P	N+P	N-P	N-P	N-P	N-P

* Indicates statistically significant difference from the untreated sample at the 5% level.

Both SRP and NO_3N concentrations showed significant temporal variation during this period of low salinity, and NO_3N also showed marked spatial variation (Fig. 3 and Johnson, 1977). Since this variation was not reflected in the phytoplankton population, despite N and P being limiting, it suggests that salinity is a major controlling factor. It thus appears that a large freshwater inflow, such as occurred in 1975 is deleterious to both phytoplankton diversity and production. If the phytoplankton is a major link, either directly or indirectly as detritus, in the zooplankton grazing system, as has been suggested (Grindley, this volume) low salinities could bring about a general reduction of productivity of the system.

Management implications

Although it therefore appears that salinities of above at least 12 and below about 60ppt. are desirable for phytoplankton production and diversity, if salinities temporarily exceeded or decreased to below these limits the adverse effect would be temporary as the system would probably be rapidly recolonised by marine and spore forming species when favourable conditions returned.

The management implications are, therefore, that contact with the sea should be maintained so that salinity fluctuations are controlled. The most favourable range is 12 to 60ppt.

THE MACROALAGE

The macroalgae of the St Lucia system have not been investigated in any detail. Millard & Broekhuysen (1970) include several species of filamentous alge, together with their recorded salinity ranges in the checklist of the fauna and flora of the St Lucia system (Table 6). During 1973, 74, and 75 the most common shoreline species were *Enteromorpha intestinalis* and a *Cladophora* sp. (Johnson, 1977). The former, in particular, often formed large masses along the shores of the northern basins. Field observations indicated that the species was present in salinities ranging from 10 to 50ppt., while plants cultivated in the laboratory grew in salinities between 10 and 70ppt., with maximum growth between 20 and 60ppt (Fig. 2). The role of these algae in the system has not been assessed.

TABLE 6: ALGAE RECORDED FROM ST LUCIA ESTUARY. (Millard and Broekhuysen 1970).

Species	Recorded salinity range (in ppt.)
Caloglossa leprievrii (Mont.) J. Ag.	10,7 - 13,9
Chaetomorpha sp.	11,2
Cladophora sp.	7,6 - 29,0
Enteromorpha	11,0 - 11,2
Lyngbya confervoides Grom	7,6 - 29,0
Microcoleus chthonoplastes Thur.	7,6 - 29,0
Polysiphonia sp.	7,6 - 29,0

THE EPIPHYTON AND EPIPELON

The epiphyton includes those algae which grow on aquatic macrophytes. Although this group may be of considerable importance (even more so than their host plants) in the production of the system during periods of macrophyte growth (Brock, 1970), it has not been studied yet.

The epipelon are the algae which inhabit te sediment surface. While the sediments in exposed areas are probably disturbed too frequently to allow a permanent colony to develop, the more sheltered areas may support considerable growth. Again, no studies have yet been carried out on this group.

GUIDELINES FOR FUTURE RESEARCH

From the findings of the research done to date on the algal population of the St Lucia system we suggest that the following areas be considered of priority importance for future studies:

i) Which energy sources support the secondary production in the St Lucia system? ;

a) What is the relative importance of the macrophyte/epiphyton and phytoplankton communities under different hydrological regimes : are macrophytes/epiphytes the major source of production during low salinity periods, and phytoplankton during high salinity periods? ; (See Appendix A)

b) How significant is benthic algal production in a turbulent system such as St Lucia? ;

c) What is the importance of nannoplankton (extremely small species of phytoplankton including flagellates) relative to netplankton in the system? ;

d) Which species are of greatest significance in the trophic dynamics of St Lucia?

ii) a) What are the relative roles of salinity, light and nutrients in determing the rate of primary production? ;

b) Which factors control the rate of primary production? ;

c) What is the reltive importance of allochthonous and autochthonous nutrient loading?

iii) What will be the potential significance, for algal productivity, of the proposed introduction of freshwater and nutrients into the region of the Narrows?

ACKNOWLEDGEMENTS

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APPENDIX A: A flow diagram of the possible effects of fresh and seawater inflow on macrophyte/epiphyte and phytoplankton production.