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ABSTRACT

The phytoplankton of the St. Lucia system were sampled during 1973, 1974 and 1975. The northern regions of the system were hypersaline at the start of the programme, but decreased to salinities below that of seawater (35 °/oo) in October, 1973, and remained low thereafter.

Autochthonous diatoms contributed most to phytoplankton volume. The population maxima of these species appeared to be controlled to some extent by salinity and temperature. Small blue-green algae and flagellates were also present. Incursions of marine neritic diatoms occurred at times of low lake levels.

Highest mean monthly phytoplankton volumes were found in False Bay and North Lake, South Lake and the Channel supporting much lower volumes. In 1975, mean monthly volumes in False Bay were considerably lower than in the two previous years.

Nutrient studies of False Bay indicated that it was both nitrogen and phosphorus limited in 1975.

INTRODUCTION

The algae of the St. Lucia system have received little attention from research workers. Cholnoky (1968) compiled a species list of the diatoms present in September 1964, with ecological notes; Millard and Broekhuyzen (1972) mention six species of littoral algae, their salinity ranges and distribution in the system; and Grindley and Heydorn (1970) give a list of some phytoplankton at Charters Creek and Lister Point in 1969.

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This project was undertaken to describe, qualitatively and quantitatively, the phytoplankton population, with particular attention to the effects of salinity changes. During 1973 and 1974 monthly samples were taken throughout the system, but in 1975 the programme was confined to False Bay, one of the northern basins, and extended to include studies on water quality using chemical analyses and algal bioassays. The division of the system into four compartments, False Bay, North Lake, South Lake and the Channel on morphometric grounds (Day *et al.*, 1954) has been followed.

METHODS

Salinity was measured in the field with an A and O optical salinometer and temperature with a mercury thermometer.

Samples for chemical analysis and bioassays were filtered through a 0,45 μ (pore size) membrane. Analyses (NH_3, NO_3, Kjeldahl N, PO_4, total P and silicate) were carried out by NIWR in Durban. Water quality of saline samples was determined using Dunaliella tertiolecta (NERC, 1974) and fresh water samples were assayed with Selenastrum capricornutum (NERP, 1971).

Phytoplankton samples were preserved with a modified Lugol's solution, and identified and counted using the Ütermohl inverted microscope technique (Lund *et al.*, 1958). Phytoplankton volume estimates were made by multiplying cell numbers for each species by the calculated cell volume for that species. Cell volumes were determined from mean dimensions of individuals from each sample and applying geometric formulae approximating the shape of that cell.

The importance of a species at various salinities and temperatures was used to gauge its response to changing conditions. Importance was calculated by arranging the population (cells ml^{-1}) into classes. Class divisions were in units of 5 for Coscinodiscus granii, and of 100 for Pleurosigma delicatulum, and were numbered in ascending order, the lowest class being designated a value of one. A matrix was drawn up relating class to numbers of occurrence (frequency) of populations in each class. The product of the frequency and class number was the Importance Value. This value is therefore weighted in favour of large populations, although all populations are represented.

RESULTS AND DISCUSSION

Physical Factors

Water level is important in the general hydrology of St. Lucia, as when the level is low, sea water enters the system, thereby increasing the salt load. The direct effect of fluctuating levels on the phytoplankton is minimal. More important is the associated factor, salinity. Being such a large and long system it would not be surprising to find that the various compartments (Fig. 1) behave differently. Those nearer the mouth are subject to direct influence from the sea, and although the salinity range is not large (15-37 ^{o}/oo), it changes fairly frequently (Fig. 2). The maximum period of a salinity seldom exceeds one month. As may be expected, salinities do not exceed that of the sea (35^{o}/oo) to any extent, but frequently drop below it. (15^{o}/oo).

Compartments further from the direct influence of the sea experience gradual salinity increases as water is lost by evaporation during dry seasons. Hypersaline conditions are not uncommon and may last for several months, although they may drop very quickly, especially when fresh water inflow is rapid. Thus in False Bay salinities decreased from 45^{o}/oo in September 1973 to 10^{o}/oo in October 1973. (Fig. 2). North Lake does not show such rapid fluctuations because the rate of inflow is slower as the Mkuze swamps hold back water, retarding its discharge into the system. South Lake is further from the major sources of fresh water and therefore receives a mixture of fresh and saline water, resulting in gradual salinity decreases.

Thus the most rigorous conditions for phytoplankton are found in False Bay, and the least rigorous in South Lake.

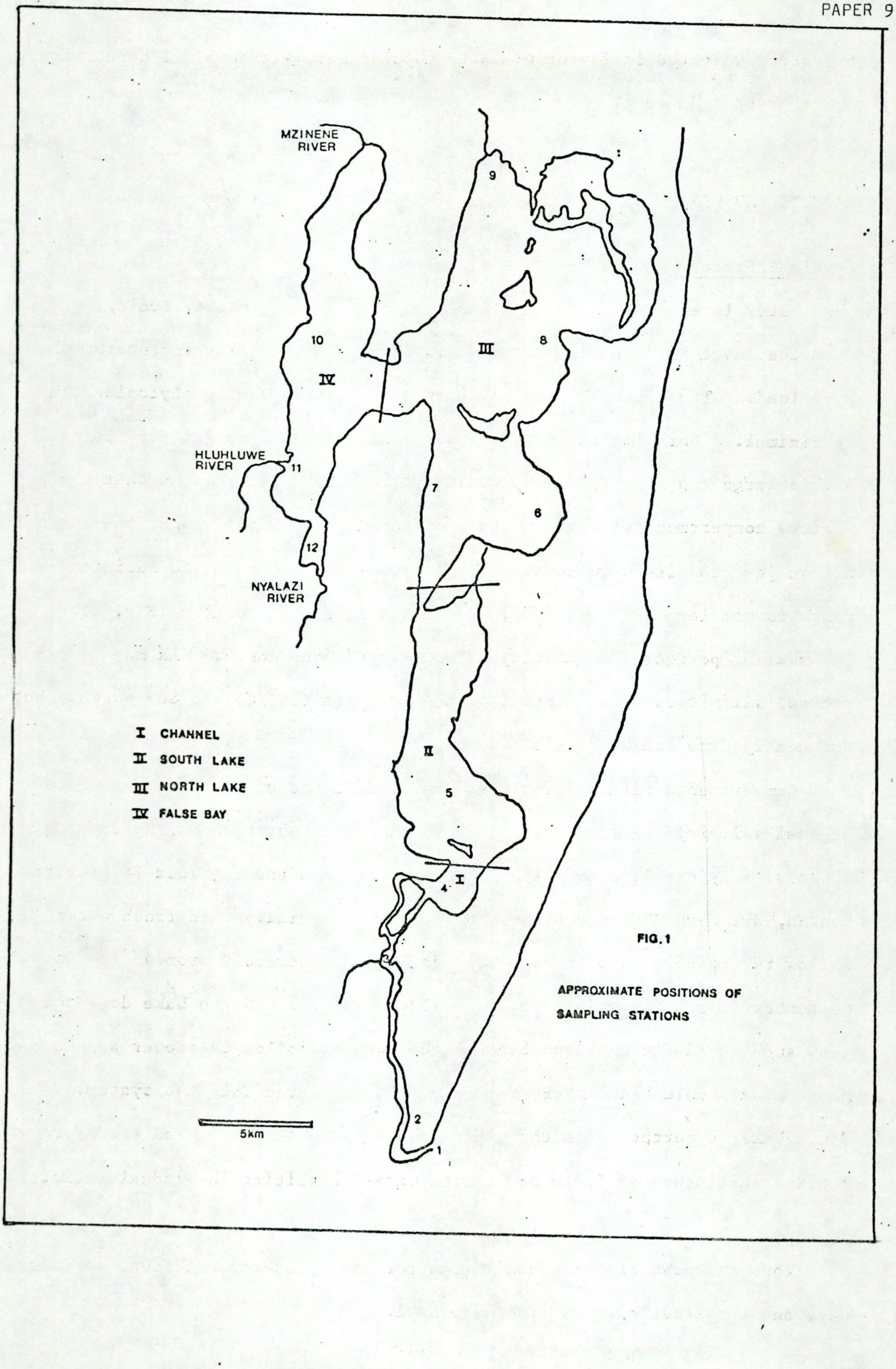
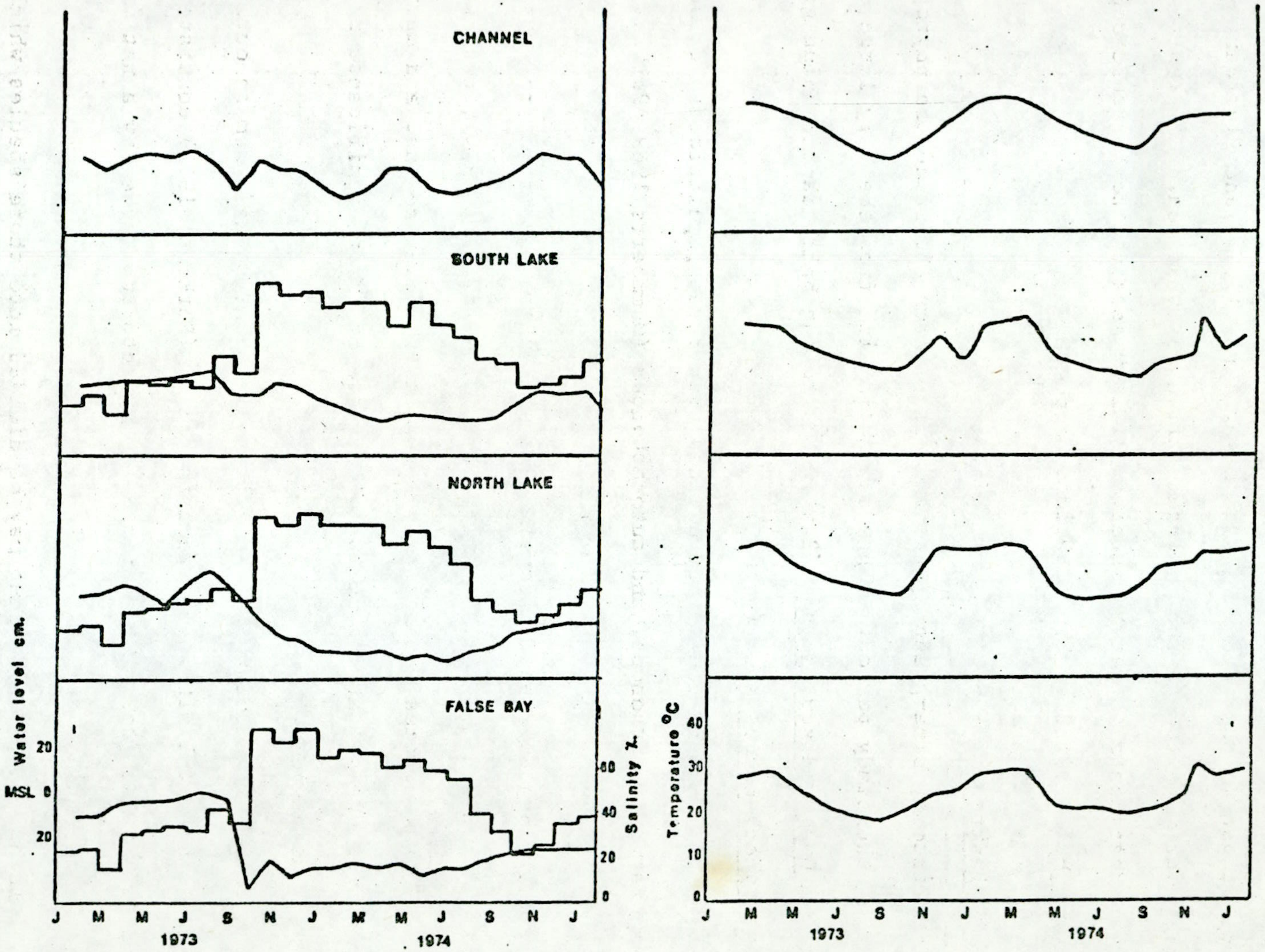


FIG.1

APPROXIMATE POSITIONS OF SAMPLING STATIONS

Fig.2: Water levels (cm), salinities (°/..), and temperatures (°C) in the four compartments of St.Lucia during 1973 and 1974.



The effect of seawater on the water temperature is noticeable in the Channel (Fig. 2). A seasonal temperature cycle is marked, and temperatures range between 15 and 30°C. In the northern regions temperatures may rise above those in the Channel (South Lake, April 1974), and fluctuate more irregularly, although the dominant influence is season. Phytoplankton in all compartments therefore receives similar seasonal temperature conditions, although localised minor variations do occur.

Phytoplankton

Diatoms, blue-green algae, and flagellates dominated the phytoplankton during the study period. They ranged in size from the very large centric diatom *Coscinodiscus granii* ($2 \times 10^6 \mu^3$) to the bacteria-like blue green alga *Synechococcus* sp. ($4\text{-}10\mu^3$).

The phytoplankton may be divided into three populations: allochthonous, temporary autochthonous, and autochthonous (Mommaerts 1969, Perkins 1974) (Table 1).

Allochthonous populations; "recently introduced from freshwater or the sea, and with a limited survival potential" (Perkins, 1974), consisted of fresh water species occasionally found at the river mouths, and marine species sometimes present at the mouth. They are of minor significance in the system as a whole.

Temporary autochthonous populations: "introduced from an outside area and capable of limited proliferation only" (Perkins, 1974) consisted of marine neritic (coastal) diatoms carried into the system by a net inflow of seawater at times of low lake levels.

In St. Lucia this group may be divided into those species which contribute significantly to the population i.e. *Rhizosolenia setigera* and *R. stolterfothii* and those which, even when present, occur in low numbers i.e. *Biddulphia mobiliensis*, *Chaetoceros lorenziana* and *Actinoptychus splendens*. Clearly the former are more easily and reliably sampled than the latter.

R. setigera has been described as a neritic species favouring cold waters (Hendey 1937) and by Hustedt (1930) as being eurythermal and euryhaline. Its distribution in St. Lucia supports the observation that it is neritic, since it is temporary, and appeared to spread from the Channel in July/September 1974 to other parts of the system including False Bay (Table 2). Between December 1974 and February 1975 in False Bay it occurred at salinities and temperatures of between 5 and 24°/oo and 25 and 28,5°C respectively, which supports the view that *R. setigera* is euryhaline and can tolerate temperatures higher than would normally be ascribed to a cold water species.

R. stolterfothii has a distribution pattern similar to that of *R. setigera* (Table 2). It has also been described as a neritic species (Hendey 1937, Hustedt 1930). Margalef (1957) (in Mommaerts 1969) has observed that this species is tolerant of low salinities and may be dominant at salinities of below 20°/oo. In St. Lucia it was present in False Bay when salinities ranged between 5 and 24°/oo, and was abundant (185×10^3 cells l^{-1}) at the Hluhluwe river mouth at 8°/oo. It is significant, however, that during the previous months salinities did not drop below 20°/oo.

Three species, *Biddulphia mobiliensis*, *Chaetoceros lorenziana* and *Actinoptychus splendens*, comprise the group that is generally present in low numbers. All three have been described as neritic by Hendey (1937) or Hustedt (1930), and are irregular in their distribution in St. Lucia. *B. mobiliensis* appeared to be most tolerant of widely ranging salinities (4 to 45°/oo) which taken together with the frequency, suggest that it may be euryhaline. *C. lorenziana* may be less tolerant of salinity, having been noted only between 24 and 38°/oo. *A. splendens* occurred on only two occasions and therefore little may be concluded in respect of response to salinity fluctuations.

Autochthonous populations have been defined as "permanent residents" (Perkins 1974). These are organisms that have adapted to conditions in the system.

Table 1: DIVISION OF THE PHYTOPLANKTON INTO ALLOCHTHONOUS TEMPORARY AUTOCHTHONOUS AND AUTOCHTHONOUS GROUPS

ALLOCHTHONOUS	TEMPORARY AUTOCHTHONOUS	AUTOCHTHONOUS
	Fresh water species	
Cosmarium sp. Scenedesmus sp.		
	Marine species	
Asterionella japonica Cleve. Syracosphaera sp. Ceratium sp. Thalassiothrix sp.	Actinoptychus splendens. (Shabd) Ralfs Rhizosolenia stolterfothii H. Peragallo Rhizosolenia setigera Brightwell Chaetoceros lorenziana Grunow Biddulphia mobiliensis Baily	Coscinodiscus granii Gough
	Brackish water species	
		Chaetoceros subtilis Cleve Pleurosigma ? delicatulum Nitzschia longissima (Breb) Ralfs Melosira dubia Kützing Melosira nummuloides (Pillw.) C.A. Agardh. Anabaenopsis sp. Synechococcus sp. Synechococcus ? leopoldiensis Dino flagellates Flagellates

Table 2: DISTRIBUTION OF RHIZOSOLENIA STOLTERFOTHII AND R. SETIGERA IN ST. LUCIA.

		CHANNEL	SOUTH LAKE	NORTH LAKE	FALSE BAY
1973	Jan-Mar				
	Apr-June	Rs(P)			
	July-Sept				
	Oct-Dec				
1974	Jan-Mar	Rs(P)			
	Apr-June				
	July-Sept	Rs(P)			
	Oct-Dec	RS(P)	Rs(C) RS(C)	Rs(C) RS(P)	RS(P)
1975	Jan-Mar				Rs(P) RS(C)
	Apr-June				
	July-Sept				
	Oct-Dec				

RS - *R. stolterfothii* (P) - Present
Rs - *R. setigera* (C) - Common (>50×10^3 cells/l)

Coscinodiscus granii, although described as a neritic species by Hendey (1937) was most common in North Lake and False Bay, where, in August 1974 there was an approximately sixfold increase in the population. This, taken together with its presence throughout the study period imply that it is a "permanent resident", and occurrence is not determined by input from the sea. Maximum numbers usually occurred at salinities of between 16 and 24°/oo, although increases were observed at 48-50°/oo (Fig. 3). Temperature did not appear to be important, since similar numbers occurred at 18 and 30°C with no distinct optimum.

Pleurosigma delicatulum was very common, particularly in the northern regions. Population maxima (up to 10^6 cells l^{-1}) were observed in February 1973, January 1974 and January 1975 in False Bay, at salinities of 40, 15 and 24°/oo, although these blooms only occurred at temperatures of 28°C and above (Fig. 4). Thus, whilst this species is usually present in low numbers, population increases only occur at high temperatures. Because of the wide size variation observed in these populations, specific identification should be regarded as tentative. However, P. delicatulum is described by Peragallo (1897) as widespread under brackish conditions.

Nitzschia longissima was common in samples, particularly from the northern regions. During March 1973 populations reached a maximum in the Channel when salinity and temperature were 24 - 36°/oo and 30°C respectively. In 1975 however, several peaks were noted in False Bay, suggesting that temperature was not very important. Considering all the data it would appear that N. longissima has a salinity tolerance range from below 10°/oo to nearly 50°/oo. In a salinity and temperature tolerance experiment optimal salinity varied with temperature so that maximum growth occurred between 10 and 30°/oo at 25°C, and between 30 and 45°/oo at 35°C.

Difficulties are experienced in separating N. longissima and N. closterium taxonomically, but both occur in the marine environment although N. longissima is more common in the littoral region (Hasle, 1964; Cupp, 1943).

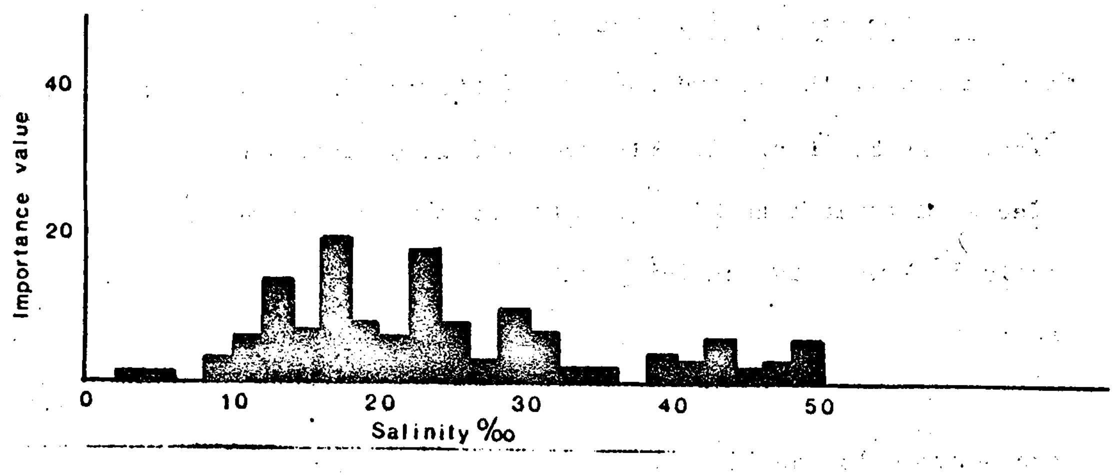


Fig.3: The response of Coscinodiscus granii to salinity in St.Lucia.

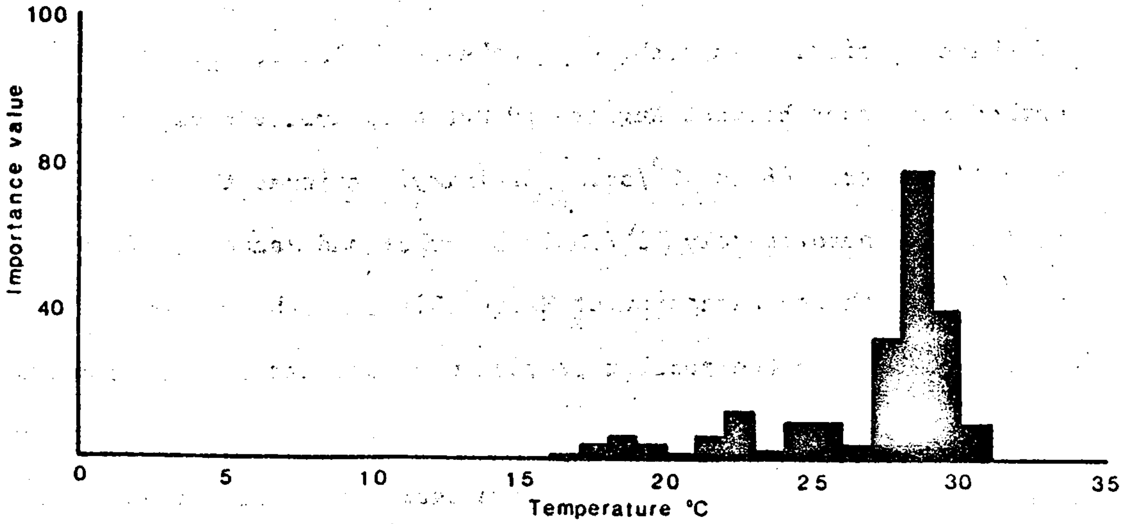


Fig.4: The response of Pleurosigma delicatulum to temperature in the St.Lucia system.

There is little doubt, however, that N. longissima is an autochthonous species in St. Lucia.

Chaetoceros subtilis has been defined as a predominantly brackish water form (Hustedt, 1930), and Caspers (1954) records it in salinity ranges of 16-18 $^o/oo$. In St. Lucia it only occurred in southern False Bay when the salinities were lower than $20^o/oo$. It was recorded in large numbers (360×10^3 cells 1^{-1}) when the salinity was $13^o/oo$ at Nyalazi River Mouth. Since the salinity two months previously was $15^o/oo$ and the population was 680 cells 1^{-1}, it appears that C. subtilis is able to grow rapidly even when salinities are between 13 and $15^o/oo$.

Two species of the extremely small blue-green alga Synechococcus were recorded in most samples although less frequently in the Channel than the northern regions. Little is known of the salinity and temperature responses of these species. In both North Lake and False Bay S. leopoldiensis showed marked increases between August and October, corresponding with a decrease in salinity from 48 to $40^o/oo$. Salinity continued to decrease, reaching a minimum of approximately $12^o/oo$ in December and January, after which it rose slowly. With the exception of Mkuze River Mouth, Lister Point and Nyalazi River Mouth where the population rise was somewhat erratic, numbers continued to increase until December and January. It seems likely therefore that population growth was associated with decreasing salinities, but it is clear that growth took place even when salinities were above $40^o/oo$ and below $20^o/oo$. The second species of Synechococcus showed peaks of much shorter duration. No distinct relationship with either temperature or salinity is apparent. It does appear, however, that the two species seldom bloom together, suggesting some competitive phenomenon.

Flagellates and dinoflagellates occurred in small numbers during the study and little can be said of the factors influencing their distribution. The dinoflagellates were ovoid, which is typical of estuarine forms (Lackey, 1967). The irregular diamond shaped marine forms were found only in the mouth area. Robarts (1973) recorded both forms in Swartvlei in areas where the salinity was low.

Phytoplankton numbers are not comparable due to size differences. Thus volumes have been used to compare populations.

The largest mean monthly volumes were recorded in False Bay and North Lake in both 1973 and 1974 (Table 3). The Channel had the lowest phytoplankton volumes, and South Lake was intermediate. Compartments did not differ markedly in mean monthly volumes between 1973 and 1974, but the 1975 volume of False Bay was considerably lower than in the two previous years. Unfortunately data is not available for the rest of the system during this period.

It is interesting that False Bay and North Lake, which have the most extreme salinity ranges support the largest phytoplankton volumes. However, from the foregoing discussion it is evident that the dominant members of the flora are autochthonous species that appear to be tolerant of considerable fluctuations in salinity. Salinities did not exceed 49°/oo during the study, which was within the tolerance ranges of two of the species that were tested, i.e. Pleurosigma delicatulum and Nitzchia longissima. P. delicatulum was one of the major contributors to the population (Table 4). Coscinodiscus granii, another important form due to its large size, showed small population increases at salinities above 40°/oo (Fig. 3).

During 1975 salinities in False Bay were lower than in the two previous years (8 to 24°/oo). The autochthonous species may therefore have been exposed to salinities below their optimum, which would account for the low mean monthly volumes during that period.

Nutrients and Phytoplankton

Samples for chemical analyses and algal bioassays were taken at five stations in False Bay, and at three river stations. Data for False Bay was presented on the mean of 5 stations.

Three rivers, the Mzinene, Hluhluwe and Nyalazi flow into False Bay. The first flows intermittently (during February, March, July, October, November and December, 1975), while the last two are perennial, although

Table 3: PHYTOPLANKTON VOLUMES (μ^3 ml^{-1} month^{-1}) IN THE FOUR COMPARTMENTS OF ST. LUCIA.

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

Table 4: % CONTRIBUTION OF THE MAJOR PHYTOPLANKTON SPECIES TO THE MEAN MONTHLY VOLUME (μ^3ml^{-1}month^{-1}) IN THE FOUR COMPARTMENTS OF ST. LUCIA.

YEAR	COMPARTMENT	Coscinodiscus granii	Pleurosigma delicatulum	Remainder
1973	Channel	5	45	50
	South Lake	35	13	52
	North Lake	53	15	32
	False Bay	41	21	38
1974	Channel	40	24	36
	South Lake	26	2	72
	North Lake	84	11	5
	False Bay	62	17	21
1975	False Bay	4	78	18

most flow occurs during the summer months e.g. February and March in 1975.

The significance of input from these rivers may be gauged by their effect on the salinity of False Bay. In 1973 (Fig. 2), inflow reduced the salinity from 45°/oo to 10°/oo between successive samples two weeks apart. This implies that the volume of water entering False Bay must have been approximately four times that originally present. During 1975 (Fig. 6) salinities decreased from 16°/oo to 8°/oo in one month, a two-fold dilution. Therefore the potential for supplying nutrients is considerable, even though flow may occur over a relatively short period of time.

PO_4 - P levels in the rivers were generally low (<$20\mu gl^{-1}$), except during February when they were between 26 and $38\mu gl^{-1}$. It is interesting, however, that these levels are considerably lower than the lowest recorded by NIWR (1969), during rainy periods in the Nyalazi ($240\mu gl^{-1}$), Hluhluwe ($140\mu gl^{-1}$) and Mkuze ($160\mu gl^{-1}$) rivers. Concentrations in the lake tend to be somewhat higher, fluctuating between $9\mu gl^{-1}$ and $41\mu gl^{-1}$. Clearly therefore, inflowing water would not tend to raise the PO_4 - P level, but may rather serve to lower it during rainy periods.

Between July and December PO_4 - P levels rose from $10\mu gl^{-1}$ to $41\mu gl^{-1}$ (Fig. 5), although during this period there was very little water flowing into the lake. This rise in PO_4P seems to have its origin within the lake system, possibly in release from sediments, or during the mineralization of allochthonous and autochthonous organic material. A small inflow during October which reduced salinities from 11,2°/oo to 9°/oo (Fig. 6), resulted in a decrease in PO_4 - P level from 33,2 to $20{,}6\mu gl^{-1}$ in False Bay.

N (as NO_3N and NH_3-N) levels ranged between $11\mu gl^{-1}$ and $621\mu gl^{-1}$ in the Nyalazi river, and generally exceeded $150\mu gl^{-1}$ (Table 5). In the Hluhluwe river wide fluctuation was also apparent, ranging between 6 and $595\mu gl^{-1}$. The Mzinene river had considerably lower levels. Because of these wide fluctuations the values are difficult to relate to lake N levels which varied between 54 and $200\mu gl^{-1}$. Although N in the lake did rise between January and February (Fig. 5) when there was considerable inflow, N levels in the rivers were, however, often highest when the flow rates were low. Thus in May they were 200$\mu g l^{-1}$ (Nyalazi River) and 280$\mu g l^{-1}$ (Hluhluwe River). In October they were 621 and 346$\mu g l^{-1}$ respectively and this may account for the rise in lake concentrations from 120 - 200$\mu g l^{-1}$.

These relatively higher levels of N than PO_4-P are reflected in the algal bioassay data (Table 5) which show P to be the primary limiting nutrient between January and July, and N and P to be equally limiting between August and December. Clearly therefore, changes in N and P levels could markedly influence productivity in False Bay.

Pleurosigma delicatulum was the dominant species in the phytoplankton between January and March and accounted for the high volumes observed during this period. This species has a yearly seasonal bloom during January or February as large populations were also recorded during 1973 and 1974. The bloom appears to be controlled principally by temperature since salinities at which blooms occurred were between 12 and 45^{o}/oo.

Although the system is P limited close correlation between the standing crop and level of P is not to be expected because the fluctuations are all within the low range. Sudden small changes would not elicit a marked response in the phytoplankton. Changes in N are much greater, but as both N and P are limiting to growth, these variations would result in little change in the phytoplankton.

CONCLUSIONS

The phytoplankton of St. Lucia is predominantly autochthonous. It is well adapted to the conditions of temperature and salinity experienced during this study to the extent that the area supporting the greatest populations are those subject to the greatest salinity changes.

More intensive studies of the physico-chemical limnology of the system will be required before the roles of the allochthonous and autochthonous nutrient systems can be elucidated.

Fig.5: PO_4-P and NH_3-N + NO_3-N (ug l^{-1}) in False Bay, St.Lucia during 1975.

Vertical bars represent one standard error of the mean.

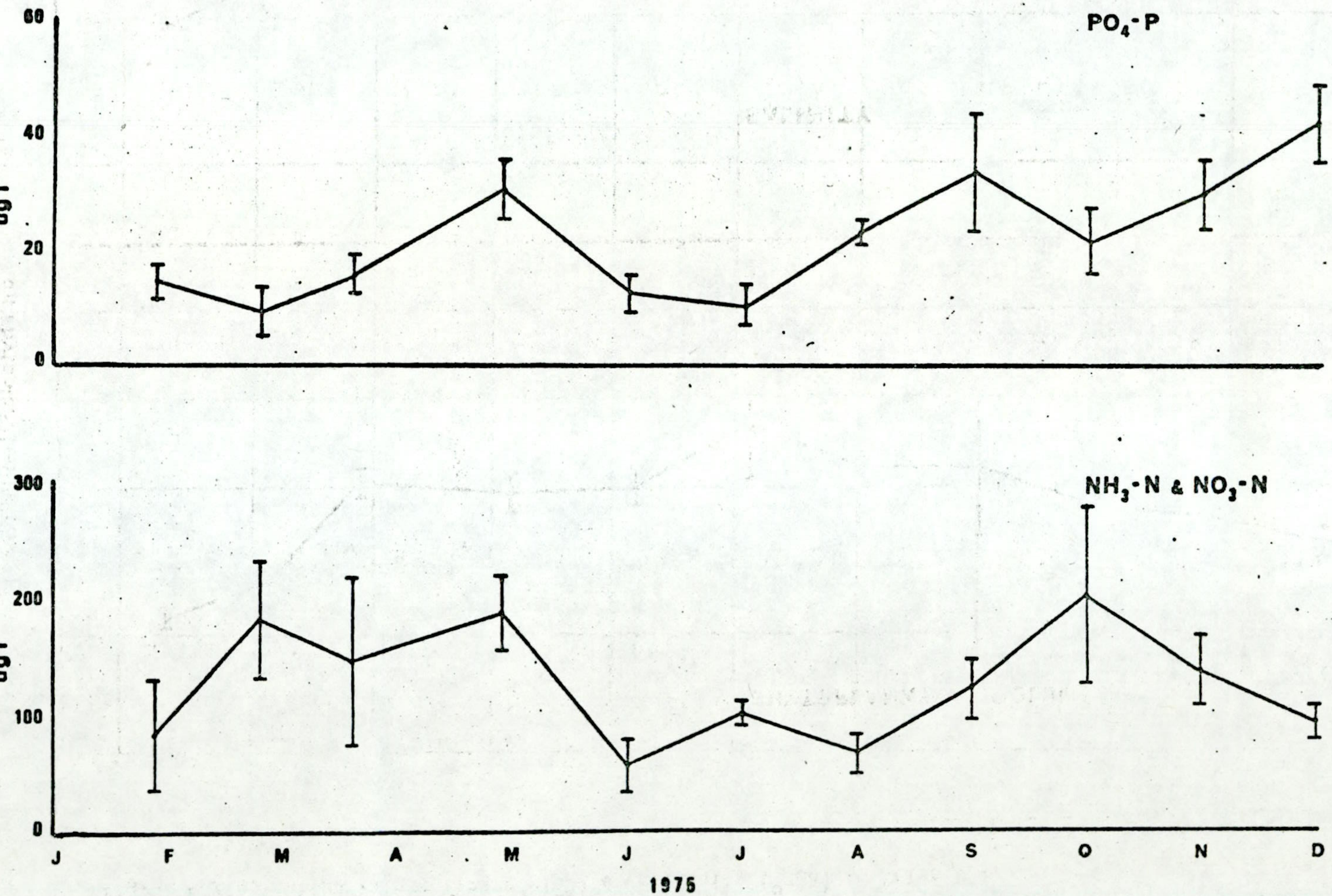


Fig.6: Phytoplankton Volume ($\log u^3 ml^{-1}$) and Salinity ($^o/oo$) in False Bay, St.Lucia during 1975. Vertical bars represent one standard error of the mean.

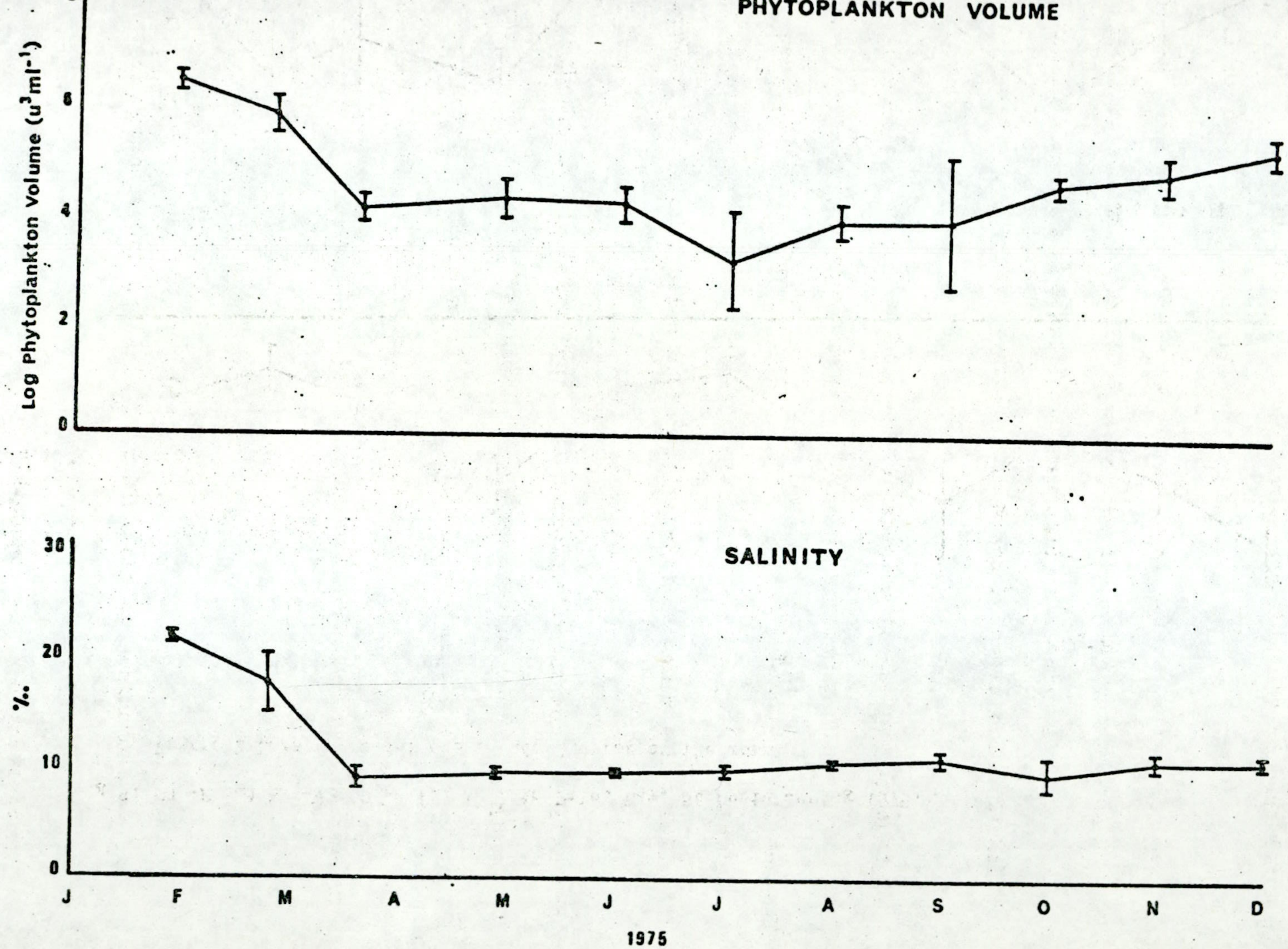


Table 5: ALGAL ASSAY GROWTH RESPONSE FROM WATER SAMPLES COLLECTED FROM FALSE BAY, 1975.

Treatment \ Month	Jan.	Feb.	Mar.	Apr.	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Control mgℓ- 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
+0,05mgPℓ-1	53,1*	46,7*	17,3*	23,9*	47,6*	31*	20,3	32,4	25,9	28,4	13,8
+1,0mgNℓ$^{-1}$	39,8	3,7	13,5	4,3	22,2	11,2	7,5	19,8	8,8	16,8	9,1
+0,05mgPℓ$^{-1}$ and +1,0mgNℓ$^{-1}$	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 at the 5% level.

TABLE 6. N(NO_3-N and NH_3N) and PO_4-P ($\mu g l^{-1}$) in the Nyalazi, Hluhluwe and Mzinene Rivers, 1975.

Month	Nyalazi River		Hluhluwe River		Mzinene River	
	PO_4-P	N	PO_4-P	N	PO_4-P	N
Jan	6	55	6	25	-	-
Feb	28	300	26	150	38	90
Mar	8	190	14	595	14	60
Apr	2	200	6	280	10	45
Jun	16	235	6	235	4	55
July	4	25	4	10,6	4,8	7,8
Aug	3,6	11	6,8	24	-	-
Sept	3	201	3	31	-	-
Oct	12	621	13	346	5	52
Nov	7	227	3	134	2	69
Dec	12	312	2	66	4	30

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