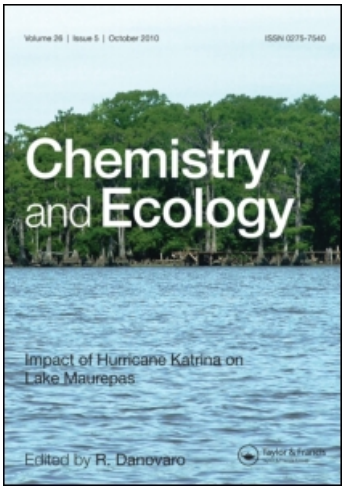

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Ecological Study of Spring-Early Summer Phytoplankton Blooms in A Semi-Enclosed Estuary

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ECOLOGICAL STUDY OF SPRING-EARLY SUMMER PHYTOPLANKTON BLOOMS IN A SEMI-ENCLOSED ESTUARY

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A sampling station in the Eastern Harbour of Alexandria was operated for 51 days between 2 March and 12 June, 1991. The harbour had different wide physical and chemical variations. Six distinct phytoplankton blooms occurred during this period. It is concluded that the physicochemical conditions affected the phytoplankton community structure and species composition. A dense diatom bloom could be maintained in a very weak and/or stabilized water column. A diatom bloom does not necessarily accompany an enhanced nutrient period. The depletion of nutrients and establishment of thermal stratification probably created favourable conditions for dinoflagellate and flagellate species to achieve blooms. The species composition could be shifted over the short term and a dense phytoplankton bloom could possibly dissipate in a few days.

KEY WORDS: Phytoplankton bloom, community structure, thermal stratification

INTRODUCTION

Changes in phytoplankton standing stock and succession are driven by a combination of autogenic and allogenic processes (reviewed in Reynolds, 1984). The time-scale of phytoplankton change is important in terms of community response to both short and long term environmental fluctuations (Harris, 1980). According to Raymont (1963), there are changes in species comprising the phytoplankton community over periods ranging from a few days to one year. Short time-scale sampling is advisable to understand phytoplankton adaptation in a system of wide variations and weekly and/or biweekly sample collection is inadequate (Winter *et al.*, 1975; Richmond, 1986; Sournia *et al.*, 1987).

Reasons for studying phytoplankton blooms are numerous (Cushing, 1975; Smayda, 1980); among them is the dominance of one or a few species which allows ecological and physiological problems to be studied conveniently in a natural population.

The present study represents an attempt to document the importance of short term sampling in the Eastern Harbour of Alexandria over a suitable time-scale to describe fully the physical, chemical and biological dynamics of a system subject to wide variations.

MATERIAL AND METHODS

Study area and sampling station

The Eastern Harbour of Alexandria is a relatively shallow, semi-enclosed basin. The harbour area is about $2.53.10^6\,m^2$, with an average depth of about 5 metres. Exchange between the harbour water and the neritic Mediterranean Sea takes place through two main openings. The harbour receives directly a discharge of $35.2.10^6\,m^3$ of untreated sewage annually, and it is also affected intermittently by a flow of sewage polluted water from the main sewage outfall (Kayet Bey) located near the harbour inlet. This outfall discharges about $96.10^6\,m^3$ of raw sewage annually to the open sea. The present study was carried out in the harbour at a fixed station where the water depth is about 5 metres. Figure 1 shows the study area and location of the sampling station.

Sampling procedure

The sampling station was operated for 51 days between 2 March and 12 June, 1991. The water temperature and salinity were measured at the surface and above the bottom. Dissolved oxygen and concentrations of inorganic nitrate, nitrite, phosphate, silicate and chlorophyll a were measured in the surface samples. Salinity was measured using a Beckman Induction Salinometer and oxygen by the Winkler method. Nutrient samples were analyzed following the methods of Strickland and Parsons (1972).

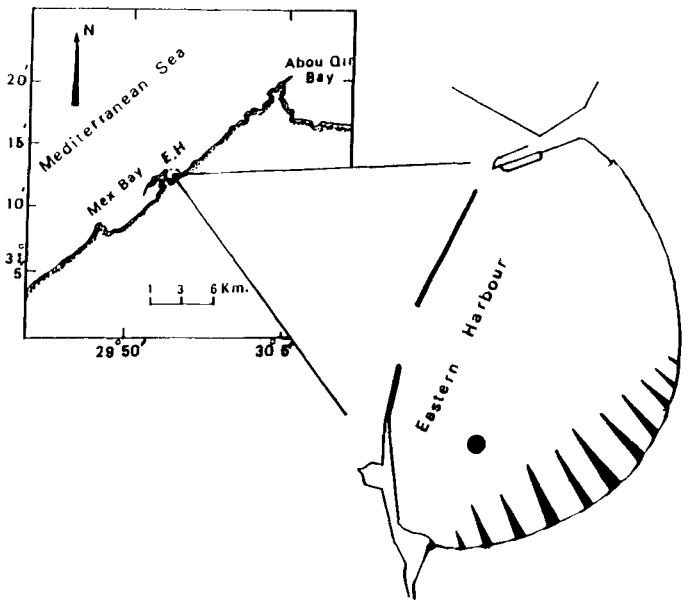

Figure 1 Sampling station (●) and locations of outfalls (▼) in the Eastern Harbour of Alexandria (E.H.).

The stability (Σ) of the water column during the sampling period was calculated (Williams, 1962) by applying the formula:

$$\Sigma = 10^{-3}\frac{\Delta\sigma_t}{\Delta z},$$

where σ_t is a quantity related to density and calculated from tables on the basis of salinity and temperature, and $\Delta\sigma_t/\Delta z$ is the rate of change of σ_t with respect to depth (z). A positive value signifies vertical stratification of the water column (Ignatiades, 1979).

Chlorophyll a content was determined for particles collected from water samples of 25–200 ml, filtered through glass fibre filters. The pigment was extracted in 90% acetone and analyzed by spectrophotometry as reported by Lorenzen (1967).

Surface phytoplankton samples for identification of species and counting were preserved by addition of neutral formalin and a few drops of Lugol's solution. Duplicate samples were examined under a research microscope and the standard error of counts calculated. Nomenclature followed mainly the check list of Hendey (1974) for diatoms, and of Parks and Dixon (1976) for other groups.

RESULTS

Physical conditions

Surface water temperature, salinity and water stability (Σ) are shown in Figure 2. Surface temperature varied between 16°C and 24.6°C. The difference between surface and bottom temperatures never exceeded 0.8°C, except for a few days in late April to early May (3.3°C) and in early June (2.3°C). Surface salinity ranged between 36.6‰ and 39.3‰. Data of water column stability showed remarkable variations, with maxima on 23 April, 5 May, 2 and 10 June. Disruption by wind action occurred on several occasions.

Nutrient content

Surface concentrations of inorganic nutrients are shown in Figure 3. Nitrate (0.1 to 5.8 μmol l^{-1}) shows high levels in early March, the pre-bloom period. A peak in early April, probably resulting from water discharge and/or mixing by wind action, was followed by low levels, accompanying phytoplankton blooms. Nitrite levels were low (0.1 to 0.95 μmol l^{-1}), generally a reverse of the nitrate trend. Silicate levels fluctuated remarkably between a minimum in mid-May, a dense diatom bloom period, (0.1 to 0.25 μmol l^{-1}) and a maximum (4.8 μmol l^{-1}) after dissipation of the diatom bloom in early March. Phosphate was relatively low (<2 μmol l^{-1}) although a relatively high concentration of 3.8 μmol l^{-1} occurred in May.

Phytoplankton community structure

The phytoplankton community structure is given in Figure 4. Six distinct phytoplankton blooms occurred during the investigation period; four blooms were of diatom species and the other two of dinoflagellate and flagellate species (Table I).

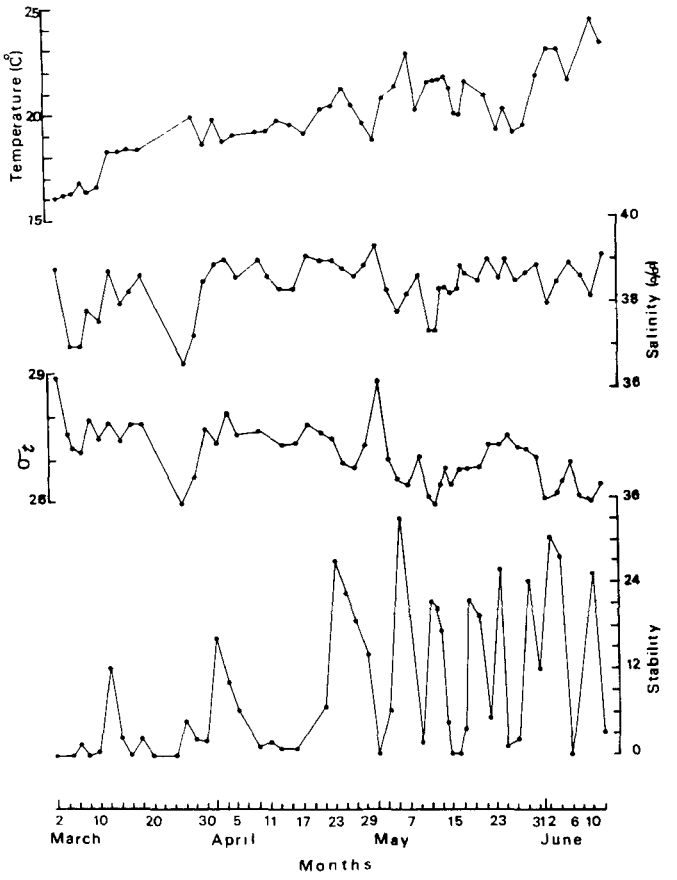

Figure 2 Surface water temperature, salinity, σ_t and water stability in the Eastern Harbour of Alexandria from 2 March to 12 June 1991.

The phytoplankton community progressed from a diatom dominated community in March and April with microflagellates dominating between diatom blooms. Dinoflagellates and flagellates were leading in the first two weeks of May and diatoms then regained dominance through the rest of the period. The standard error for the phytoplankton counts was 28.75, significant at $p = 0.1$ (t test).

Phytoplankton blooms

Dominant diatom species are shown in Figure 5.

The first (diatom) bloom

The first bloom occurred between 4 and 7 March. Stable thermal conditions were maintained over the first two days. Temperature increased slightly on 7 June (16.7°C).

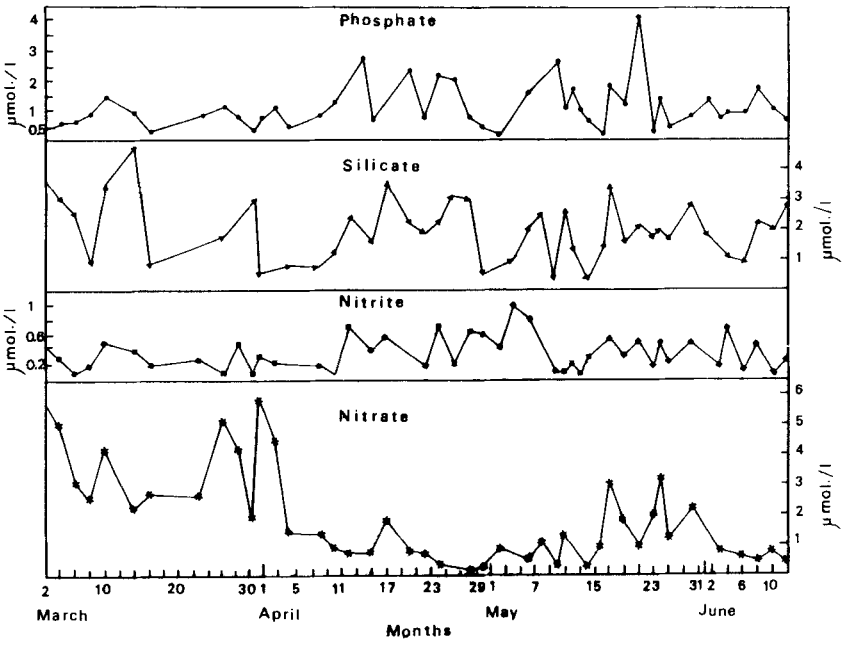

Figure 3 Surface concentrations of inorganic nutrients (µmol/l) in the Eastern Harbour of Alexandria from 2 March to 12 June 1991.

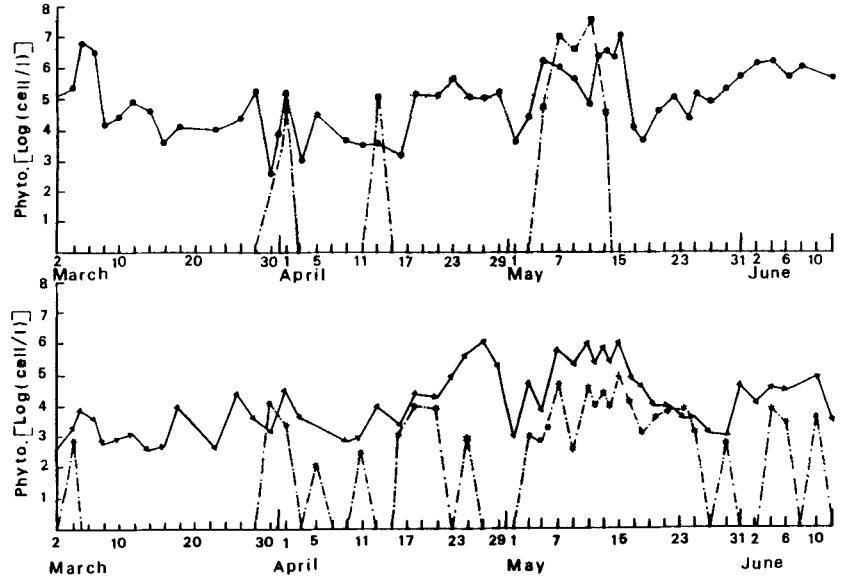

Figure 4 Phytoplankton community structure [Log(cell/l)] in the Eastern Harbour of Alexandria from 2 March to 12 June 1991.

Diatoms ●——● Flagellates ■- - -■

Dinoflagellates ←——→ *Euglena & Eutreptiella* spp. *- - -*

Table 1 Maximum density of the dominant phytoplankton species and related physical and chemical conditions in the Eastern Harbour of Alexandria from 2 March to 12 June 1991.

Date of the bloom	*Dominant species*	*Maximum density* (10^6 *cell/l*)	*Surface temperature during the bloom* (°C)	*Surface salinity during the bloom* (‰)	*Nutrient concentrations* (μmol/l) *at onset of the bloom*			
					NO_2	NO_3	PO_4	SiO_4
4–7 March	*S. costatum*	6.27	16.0–16.7	37.0–37.5	0.45	5.63	0.38	3.60
	A. glacialis	0.59						
18–23 April	*R. delicatula*	3.50	19.0–20.5	39.0–39.1	0.57	1.80	1.03	3.50
23–29 April	*P. minimum*	2.20	20.5–21.1	38.6–38.8	0.60	0.40	1.10	3.00
7–10 May	*Pyramimonas sp.*	28.30	21.5–22.8	37.3–38.6	0.20	0.55	1.58	2.50
12–15 May	*S. eostatum*	8.53	22.0	37.5–38.3		1.34		3.62
29–12 June	*C. pelagica*	0.77	19.0–22.6	38.0–39.1	0.45	2.30	0.75	2.30
	N. frigida	0.83						

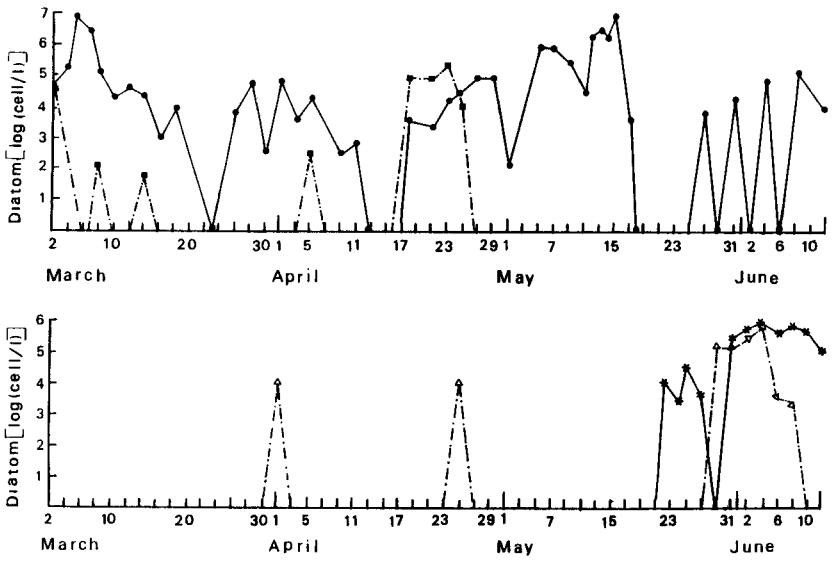

Figure 5 Dominant diatom species [log(cell/l)] in the Eastern Harbour of Alexandria from 2 March to 12 June 1991.
Skeletonema costatum ●——● *Rhizosolenia delicatula* ■-·-·-■
Ceratulina pelagica *——* *Nitzschia frigida* ▽-·-·-▽

Surface salinity was 37‰ and increased to 37.5‰ at the bottom. The water column was stable ($\Sigma = 1.15$). Nutrient concentrations were relatively low just prior to the bloom with 0.38, 3.6, 0.45 $\mu mol\,l^{-1}$ for phosphate, silicate and nitrite, but 5.63 $\mu mol\,l^{-1}$ for nitrate. The bloom consumed most of the nutrients and nitrate fell to 2.3 $\mu mol\,l^{-1}$.

The centric diatom, *Skeletonema costatum*, was the causative species, contributing a maximum density of $6.27 \cdot 10^6$ cells l^{-1} (90.37%) on 5 March. The pennate diatom, *Asterionella glacialis*, was next in abundance ($0.59 \cdot 10^6$ cells l^{-1}).

Other phytoplankton species present were *Thalassiosira rotula*, *Ceratulina pelagica*, *Chaetoceros decipiens*, *C. affine* and *Prorocentrum triestinum*.

Chlorophyll a content increased greatly from 4.3 $\mu g\,l^{-1}$ on 4 March to 15.58 $\mu g\,l^{-1}$ on the following day when oxygen was 9.15 $mg\,l^{-1}$.

The dissipation of the bloom was rapid and $0.432.10^6$ cells l^{-1} of *S. costatum* were found in surface samples on 8 March. Reasons for the dissipation of the bloom were not clear since the measured physicochemical conditions could have supported the bloom further. Other factors such as grazing and water exchange must be considered.

No distinct phytoplankton blooms were recorded until 18 April, when a second diatom bloom occurred. Temperature varied between 16.3 and 19°C, increasing as days went by.

The second (diatom) bloom

This bloom appeared between 18 and 23 April. Temperature was 19.0°C on the first day and increased to 20.5°C on 23 April. Salinity was about 39.1‰. A stable thermal

condition was observed on 18 April and the water column remained stable for the following days (Σ between 6 and 10). The bloom occurred at a time when nutrient concentrations were relatively low, 1.03, 0.57, 1.8 $\mu mol\,l^{-1}$ for phosphate, nitrite and, nitrate while silicate was 3.5 $\mu mol\,l^{-1}$. Silicate fell to 1.85 $\mu mol\,l^{-1}$ on 23 April.

The bloom was attributed mainly to the centric diatom *Rhizosolenia delicatula*, which attained a maximum density of $3.5.10^6$ cells l^{-1} (80.63% of the total). Several other diatom species were also present during the bloom: *S. costatum*, *Chaetoceros affine* and *Leptocylindrus danicus*. Dinoflagellates were also numerous: *Prorocentrum minimum*, *P. triestinum*, *Protoperidinium steinii*, *P. depressum and Scrippsiella trochoidea.*

Chlorophyll a content increased to 10.25 $\mu g\,l^{-1}$ on 23 April when oxygen was 8.9 $mg\,l^{-1}$.

The dissipation of this bloom was followed immediately by another. The relative increase in temperature (21.15°C), low salinity (38.2‰), high stability of the water column ($\Sigma = 22$) and low nitrate (0.6 $\mu mol\,l^{-1}$) probably created favourable conditions for the onset of the next bloom.

The third (dinoflagellate) bloom

The dinoflagellate species, *Prorocentrum minimum*, was the responsible species in this bloom, appearing in samples by 23 April ($0.10.10^6$ cells l^{-1}). It increased rapidly by the following day ($0.44.10^6$ cells l^{-1}), attaining a peak of $2.2.10^6$ cells l^{-1} on 27 April. Other dinoflagellate species in the bloom were *P. depressum* and *Prorocentrum micans.* Diatoms were present during the bloom, including *S. costatum*, *Chaetoceros spp.*, *Thalassiosira rotula* and *C. pelagica.*

Chlorophyll a content was 13.85 $\mu g\,l^{-1}$, reflecting the peak of the bloom on 27 April when oxygen was 8.6 $mg\,l^{-1}$.

The density of *P. minimum* decreased sharply to $0.12.10^6$ cells l^{-1} on 29 April and the bloom had dissipated by 1 May. Reasons for the dissipation could possibly include a change in water stability which fell dramatically to zero.

This bloom was followed within a week by another. The period between these two blooms was characterized by a sharp increase in temperature from 18.8°C to 22.8°C and relatively low salinity (around 38‰). The water column was stable, with a maximm on 5 May ($\Sigma = 33$). Nutrients were relatively low and phosphate ranged from 0.15 to 0.7 $\mu mol\,l^{-1}$, silicate 0. 6 to 1.0 $\mu mol\,l^{-1}$, nitrite 0.45 to 0.95 $\mu mol\,l^{-1}$, and nitrate 0.2 to 0.9 $\mu mol\,l^{-1}$.

The fourth (chlorophycean) bloom

This bloom occurred between 7 and 10 May, causing water discoloration. Microflagellate species were the causative organisms, with a maximum density of $28.3.10^6$ cells l^{-1} on 11 May. This bloom will be reported, along with other red tide blooms, in another paper (Labib, in prep.).

The fifth (diatom) bloom

This bloom occurred over three days between 12 and 15 May, less than 2 days after the dissipation of the previous one. Temperature was around 22.0°C and salinity was

relatively low (37.5–38.3‰). The water column was stable until 14 May and became mixed on the last day. The bloom consumed most of the silicate, which dropped from 3.62 to 0.35 $\mu mol\,l^{-1}$, and nitrate fell from 1.34 to 0.05 $\mu mol\,l^{-1}$. This bloom was the most dense diatom bloom with *S. costatum* as the causative organism, reaching $8.53.10^6$ cells l^{-1} on 15 May.

Other diatom species within the bloom were relatively scarce and included *Chaetoceros affine*, *C. didymum*, *Nitzschia longissima* and *Bellarochea malleus*. Dinoflagellates persisting during the bloom were *P. minimum* and *S. trochoidea*.

Chlorophyll a content indicated a peak of the bloom on 15 May (28.69 $\mu g\,l^{-1}$), when oxygen was 10.35 $mg\,l^{-1}$.

Reasons for the dissipation of the bloom on 16 May could possibly include the severe impoverishment of silicate in the surface water on 17 May (0.1 $\mu mol\,l^{-1}$). Several other species shared dominance of the phytoplankton community during the last two weeks of May, yet no bloom developed.

The last (diatom) bloom

This bloom occurred during the two weeks from 29 May to 12 June. Temperature increased significantly from 19°C on 29 May to 22.6°C on 10 June. Salinity varied between 38 and 39‰. The water column was highly stable (except on 6 June), with a maximum on 2 June ($\Sigma = 31$). Nutrients just prior to the bloom on 29 May were 0.75, 2.8, 0.45 and 2.3 $\mu mol\,l^{-1}$ for phosphate, silicate, nitrite and nitrate, respectively. The bloom consumed most of the nitrate which fell to 0.38 $\mu mol\,l^{-1}$ on 12 June. The bloom was a multispecies one. The centric diatom, *Ceratulina pelagica*, and the pennate diatom, *Nizschia frigida*, were the causative organisms. The latter species became dominant by the 6 June. The maximum density of *C. pelagica* was recorded on 4 June ($0.77 \cdot 10^6$ cells l^{-1}), while that of *N. frigida* occurred on 8 June ($0.83 \cdot 10^6$ cell l^{-1}).

Other diatom species present during the bloom were numerous, among them *L. danicus*, *Chaetoceros spp. and Thalassionema nizschioides* were important. The first species attained $0.36 \cdot 10^6$ cells l^{-1} on 2 June. Dinoflagellate species were insignificant during the bloom, mostly represented by *Prorocentrum spp.* Chlorophyll a was high on 2, 4 and 8 June (12.5, 13.8 and 10.0 $\mu g\,l^{-1}$). Dissolved oxygen reached 7.25 $mg\,l^{-1}$ on 4 June.

DISCUSSION

The water temperature, salinity and stability showed remarkable variations through the whole investigation period. The onset of both the first and the second diatom blooms showed that physical perturbation in the water column could determine the predominance of diatoms, similar to the finding of Mukai and Takimoto (1985) and Ishizaka *et al.* (1986). However, a dense diatom bloom could be maintained in either a weak or a well stabilized water column as observed during the last bloom.

Nutrient concentrations were mainly determined by the volume of water discharged to the harbour, mixing by wind action and phytoplankton growth. The first and second diatom blooms occurred with relatively high nitrate and/or silicate concentrations.

Skeletonema costatum, the causative organism of the first bloom, grows well in an environment of low turbulence with an adequate nutrient supply (Estrada *et al.*, 1988). However, the last diatom bloom showed that low to intermediate nutrient concentrations are still sufficient for diatoms to grow. The pennate diatom, *N. frigida*, dominated the community in these conditions. The depletion of nutrients and increased surface temperature, and by implication the establishment of thermal stratification, created favourable conditions for dinoflagellate and flagellate species to dominate the algal community between 23–27 April and 7–10 May. Flagellate blooms in thermally stratified—low nutrient waters were earlier reported by Takahashi *et al.* (1977), Edler and Olsson (1985).

It is difficult to assess the importance of the physical and chemical conditions for regulation of phytoplankton dynamics in a system of wide variations where they may alter the species composition.

The phytoplankton species composition shifted over the short term and dense blooms developed and dissipated within only a few days. The centric diatom, *R. delicatula*, the causative organism of the second bloom (maximum density on 23 April), was replaced by a dinoflagellate species, *P. minimum*, which attained maximum density on 27 April. A change from a microflagellate to a centric diatom species took place within 2 days, when dissipation of the former was replaced by *S. costatum*. The same time-scale was observed in the last diatom bloom when the centric diatom, *C. pelagica*, was replaced by the pennate species, *N. frigida*.

In conclusion, a short time-scale sampling schedule is advised for describing physical, chemical and biological conditions in a system of wide variation. Weekly or biweekly sample collections would have been inadequate to characterize the rapidly varying conditions

References

Cushing, D. H. (1975) *Marine Ecology and Fisheries*. Cambridge University Press, Cambridge 278 pp.

Edler, L. and Olsson, P. (1985) Observations on diel migration of *Ceratium furca* and *Prorocentrum micans* in a stratified bay on the Swedish west Coast. In: *Toxic Dinoflagellates*. (Anderson, White, and Baden, Eds) Elsevier, New York pp. 195–200.

Estrada, M., Marrase, C. and Alcaraz, M. (1988) Phytoplankton response to intermittent stirring and nutrient addition in marine microcosms. *Mar. Ecol. Prog. Ser.* **48:** 225–234.

Harris, G. P. (1980) Temporal and special scales in phytoplankton ecology. Mechanisms, methods and management. *Can. J. Fish. Aquat. Sci.* **37:** 877–900.

Hendey, N. I. (1974) A revised check-list of British marine diatoms. *J. Mar. biol. Ass. U. K.* **54:** 277–300.

Ignatiades, L. (1979) The influence of water stability on the vertical structure of a phytoplankton community. *Mar. Biol.* **52:** 97–104.

Ishizaka, J., Takahashi, M. and Ichimura, S. (1986) Changes in growth rate of phytoplankton in local upwelling around Izu Peninsula, *Jap. J. Plank. Res.* **8:** 169–181.

Lorenzen, C. J. (1967) Determination of chlorophyll and pheopigments: Spectrophotometric equations. *Limnol. Oceanoger.* **12:** 343–346.

Mukai, T. and Takimoto, K. (1985) Effect of environmental gradients concerning water qualities on the structure of phytoplankton community in the coastal sea. *Estuar. Coast. Shelf Science.* **20:** 169–181.

Parke, M. and Dixon, P. S. (1976) Check-list of British marine algae. Third revision, *J. mar. biol. Ass. U. K.* **56:** 527–594.

Raymont, E. G. (1963) *Plankton and Productivity in the Oceans*, Pergamon Press. Oxford, 660 pp.

Reynolds, C. S. (1984) Phytoplankton periodicity: the interaction of form, function and environmental variability. *Freshwater Biology*, **14:** 111–142.

Richmond, A. (1986) Cell response to the environmental factors. In: *Handbook of Microalgal Mass Culture*. Richmond, A. (ed)., CRC Press, Florida, pp. 69–99.

Smayda, T. J. (1980) Phytoplankton species succession. In : *The Physiological Ecology of Phytoplankton*, (Morris, I., ed.), Blackwells, Oxford. pp. 493–570.

Sournia, A., Birrien, J., Douville, L., Klein, B. and Violler, M. (1987) A daily study of the diatom spring bloom at Roscoff (France) in 1985. The spring bloom within the annual cycle. *Estuar. Coast. Shelf Science* **25:** 355–367.

Strickland, J. D. and Parsons, T. R. (1972) *A Practical Handbook of Sea Water Analysis*, 2nd ed. *Bull. Fish. Res. Bd. Canada* No. **167,** 310 pp.

Takahashi, M., Seibert, D. L. and Tomas, W. H. (1977) Occasional blooms of phytoplankton during summer in Saanich Inlet. *Deep-Sea Res.* **24:** 775–780.

Williams, J. (1962) *Oceanography*, Little, Brown Boston & Co. pp. 242.

Winter, D. F., Bance, K. and Anderson, G. C. (1975) The dynamics of phytoplankton bloom in Puget Sound, a fjord in northwestern U.S.A. *Mar. Biol.* **29:** 139–147.