PHYTOPLANKTON IN SOUTHAMPTON WATER

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In contrast to adjacent areas, such as Portsmouth and Langstone Harbour, photosynthetic processes in Southampton Water appear to be dominated by planktonic rather than benthic algae, even though benthic weed beds, notably *Ulva*, seem to have been more extensive in the past (Royal Commission on Sewage Disposal, 1911). The seasonal cycle of phytoplankton in the estuary is typified by a single summer bloom, rather than the spring and autumn bloom of adjacent coastal waters. It would appear from the studies of Raymont and Carrie (1964), Savage (1965), de Souza Lima and Williams (1978), Diwan (1979) and Bryan (1979) that blooms may occur between May and July, and either take the form of a single intensive bloom or a more protracted one. Chlorophyll *a* values vary from about 1-2μg l^{-1} in the winter months to 10-20μg l^{-1} during the summer, and may exceed 40μg l^{-1} at the peak of the bloom. As with other phytoplankton associated parameters, e.g. concentration of phosphate and nitrate, there is little evidence of vertical gradients, although there is typically a decrease in the maximum chlorophyll *a* value from mid-estuary seawards. A series of seasonal profiles of chlorophyll *a* concentration determined in surface water samples taken at N.W. Netley are shown in Figure 1.

Savage (1965) reported the dominant algal species to be *Skeletonema costatum, Asterionella japonica* and *Thallassiosira* sp., and provided a list of the planktonic algae collected during a 10 min. tow of a 200 m.p.i. (nominally 125μ) net. During the spring, *Coscinodiscus* spp. (mainly *radiatus*), *Lithodesmium undulatum* and *Rhizosolenia setigera* were present while *A. japonica, L. undulatum* and *R. setigera* predominated in the summer, and these were joined by *Biddulphia alternans* and *B. mobiliensis* in the autumn. Burkill (1978) also noted *S. costatum, A. japonica* and *Thallassiosira* sp. amongst the more abundant diatoms in the estuary and gave the following phytoplankton series. *Skeletonema* was abundant in the early spring, followed by *Navicula* sp. and *B. sinensis.* In April *Coscinodiscus* spp. and *Thalassionema* sp. were present and by August *A. japonica* dominated the plankton. In the autumn, the commonest species were *B. sinensis, Bacillaria paradoxa* and *Coscinodiscus* spp. The dinoflagellates *Peridinium* spp., *Gonyaulax* spp. and *Prorocentrium micans* were also common during the midsummer months.

Another organism known to give rise to intense blooms is the photosynthetic ciliate *Mesodinium rubrum* which can occur in such densities as to discolour the water and impart a distinct reddish hue. This species may be a long standing resident of Southampton Water, as the Royal Commission on Sewage Disposal (1911) made reference to "the annual occurrence of a red coloration of the water". Although this report attributed the cause to the dinoflagellate family Peridineae, no intense peridinium blooms are found in the region at present, and it is probable that *Mesodinium* was to blame. In contrast to the red tides caused by dinoflagellates, bloom *Mesodinium* is not known to produce a toxin.

Bryan (1979) made an extensive study of photosynthesis and heterotrophic activity in Southampton Water at approximately monthly intervals over a 13 month period during 1974-75. Very high rates in excess of 1mg C fixed l^{-1} day^{-1} (2-3gC fixed m^{-2} day^{-1}) were observed during bloom periods, falling to less than 0.01mg C fixed l^{-1} day^{-1} during the winter. In common with chlorophyll *a*, there was a downward gradient in photosynthesis from the mid-part of the estuary seawards. In the upper part of the estuary, the annual phytoplankton productivity was estimated to be in the region of 150gC fixed m^{-2} y^{-1}, falling to less than 100gC m^{-2} y^{-1} at the mouth of the estuary. The average annual productivity for the estuary in the year studied was 123 gC m^{-2} y^{-1} and this figure now seems to be typical of temperate estuaries (Williams, 1979). Savage (1967) fractionated the chlorophyll and photosynthetic activity (the ^{14}C-technique) and found that over a period of 18 months, the percentage of total chlorophyll *a* retained

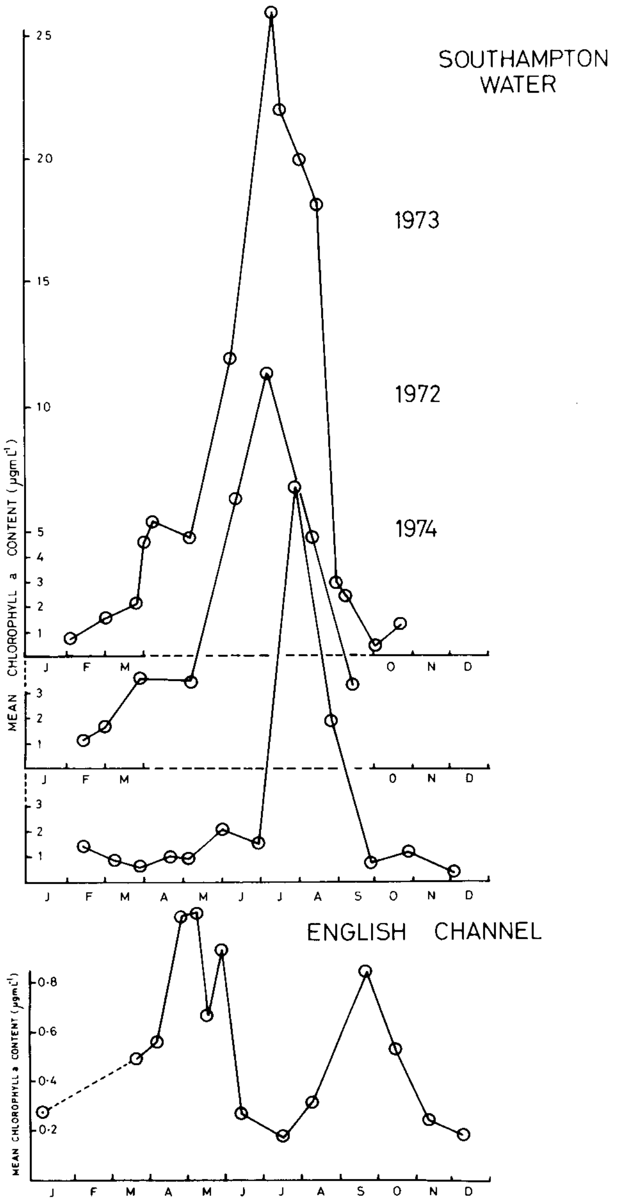

Fig. 1 Seasonal variations in chlorophyll a (corrected for phaeophytin) at N.W. Netley, together with data from the English Channel (provided by E.I. Butler) for comparison.

by N25 netting (aperture size about 60μ) never exceeded 14% and averaged 7%. Fractionation of ^{14}C-fixed by sea-water samples on five occasions between February and June showed that, on average, only 9% of the total carbon assimilation was by phytoplankton retained on 60μ aperture netting, 18% by those cells on 20μ aperture netting, and 73% by those passing through the 20μ apertures.

Diwan (1978) and Burkill (1978) have studied bacterial and protozoan abundance in Southampton Water. Diwan (1978) reported that tintinnids and dinoflagellates dominated the Protozoa with the most common tintinnids being *Tintinnopsis lohamani* and *T. platensis*, and the predominant dinoflagellate, *Peridinium micans* with occasional blooms of *P. trochoideum* and *Gonyaulax spinifera*. Burkill (1978) found thirteen species of tintinnids; the dominant forms were *Stenosemella ventricosa* and *Tintinnopsis heroides* while *S. nivalis, S. producta, T. acuminata, T. baltica, T. campanula, T. parva, T. turbo, Parafavella denticulata, P. obtusangula, Helicostomella subulata and Favella serrata* were also present. In addition, significant naked ciliate populations were noted, mainly from the oligotrich group of the Spirotricha. However, as with other Protozoa, small flagellates and Foraminifera, identification was difficult and not attempted (Tables 1, 2).

Table 1 Typical ranges of cell numbers and wet biomass of protozoa and bacteria (after Diwan, 1978).

	Cell Number (Cell ℓ^{-1})	Wet Biomass ($\mu g\ \ell^{-1}$)
Tintinnids	10 - 400	1 - 10
Ciliophera (other than Tintinnids)	1 - 100	0.05 - 1.0
Prorocentrum micans	5 - 400	0.5 - 2.5
Mastigophera (other than *Prorocentrum micans)*	2 - 2000	0.05 - 1
Total ciliates	50 - 2500	1 - 15
Total bacteria	50,000 - 800,000	10 - 800

Several estimates of the planktonic oxygen consumption have been made (de Souza Lima and Williams, 1978; Diwan, 1978; Bryan, 1979) and all exhibit essentially the same pattern with highest rates (400-500μg O_2 l^{-1} d^{-1}) during the summer months associated with the phytoplankton bloom, followed by lower rates (100-200μg l^{-1} d^{-1}) out of the bloom period (Fig. 2). The rates in the winter are argued to be in excess of the endogenous input and to be sustained by external sorces notably industrial discharge (de Souza Lima and Williams, 1978).

In 1973 the Hampshire River Authority contracted

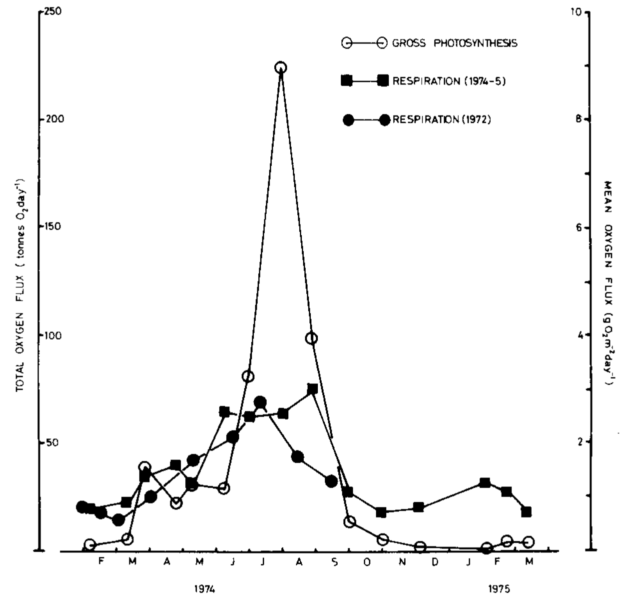

Fig. 2 Seasonal variations in photosynthetic and respiratory oxygen consumption. Values are computed means and totals for the estuary (Williams, unpublished).

Table 2 The standing stocks of naked and tintinnid ciliates, bacteria, phytoplankton and total microseston at Calshot (Data expressed as μgC litre^{-1}).

	Naked* Ciliates	Tintinnids*	Bacteria*	Phytoplankton**	Microseston
January	0.05	0.59	7.82	66.3	2435
February	0.20	0.68	9.58	111.3	2806
March	0.10	0.57	3.21	81.6	665
April	0.09	0.71	8.23	85.8	948
May	2.90	3.21	6.58	201.6	1044
June	0.50	0.97	4.11	111.0	788
August	0.19	1.44	20.98	328.2	691
September	0.30	1.18	57.24	101.4	2844
October	0.04	2.58	8.54	89.4	903
November	0.09	0.64	8.54	75.0	1252
Mean value	0.46	1.26	13.48	125.2	1438

* Abstracted from Diwan (1978)

** Calculated from chlorophyll *a* data assuming a chlorophyll *a* carbon ratio of 60:1

The data from Diwan is for 1974, the remaining data is for 1975. The January and February values are the mean values obtained from January 1974 and February 1974 and 1975 respectively.

Portsmouth Polytechnic to make a general survey of the effects of effluent discharge on Langstone Harbour. Although the main emphasis of the work was directed towards benthic organisms, the final report contained some data on the phytoplankton (Portsmouth Polytechnic, 1976). Chlorophyll *a* levels in the water were found to fall within the range 1-5μg l^{-1}, which is comparable to the levels found in the adjacent Solent, suggesting little additional growth of plankton in the harbour itself. Identifications of the diatoms occurring in the plankton from Langstone Harbour were made and are shown in Table 3.

TABLE 3 Planktonic Algae of Langstone Harbour

Division CHRYSOPHYTA
Class BACCILARIOPHYCEÆ
Order BACILLARIALES

SUBORDER ACHNANTHINEÆ
FAMILY ACHNANTHACEÆ
Achnanthes longpipes
Cocconeis scutellum var scutellum
Cocconeis speciosa
Cocconeis sublittoralis

SUBORDER BIDDULPHINEÆ
FAMILY BIDDULPHINACEÆ
Biddulphia alterans
Biddulphia aurita
Ditylum brightwellii
FAMILY CHAETOCERACEÆ
Chaetoceros sp.

SUBORDER COSCINODISCINEÆ
FAMILY ACTINODISCACEÆ
Actinoptycus senarius
Coscinodiscus eccentricus
Melosira sp.
Podosira stelliger
Skeletonema costatum

SUBORDER FRAGILARIINEÆ
FAMILY FRAGILARIACEÆ
Asterionella japonica
Grammatophora oceania var *subtilissima*
Licmophora sp.
Raphoneis amphiceros
Raphoneis surirella
Synedra sp.

SUBORDER NAVICULINEÆ
FAMILY BACILLARIACEÆ
Bacillaria paxillifer
Nitzschia closterium
Nitzschia seriata
FAMILY CYMBELLACEÆ
Amphora hyalina
FAMILY NAVICULACEÆ
Amphipleura rutilans
Diploneis bombus
Gyrosigma balticum
Gyrosigma wansbeckii
Navicula grevilleana
Navicula lyroides
Navicula hyalina
Navicula 'others'
Pleurosigma angulatum
Trachyneis aspera

SUBORDER SURIRELLINEÆ
FAMILY SURIRELLACEÆ
Surirella gemma
Surirella fastuosa

SUBORDER RHIZOSOLENIINEÆ
FAMILY RHIZOSOLENIACEÆ
Rhizosolenia hebetata forma semispina
Rhizosolenia styliformis

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