

## PHOSPHORUS AND SILICON IN SEA WATER OFF PLYMOUTH DURING 1954

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(Text-figs. 1-4)

Analyses of water collected during 1954 at the International Hydrographic Station E1 (lat.  $50^{\circ} 02' N.$ , long.  $4^{\circ} 22' W.$ ) are here reported in the same form as in a previous report (Armstrong, 1954). The methods of collection and analysis of samples were unchanged.

There are no observations below 30 m. at the end of the year because of a mishap with the sampling gear in November, and because bad weather curtailed work at sea in December.

### TEMPERATURE AND SALINITY

The vertical distribution of temperature during the year is shown in Fig. 1. The water column showed vertical uniformity until May. The minimum surface temperature recorded was  $9.0$  on 12 March. The mean salinity increased between 19 January and 16 February from  $35.31$  to  $35.37$ . The significance of this small change is discussed below. On 10 May, after rough weather there was only  $0.5^{\circ} C.$  difference between the top and bottom of the water column, but on 19 May the difference was  $2.3^{\circ} C.$  and there was a marked thermocline at 30 m. This thermocline remained at 25 to 30 m during the summer, but had broken down by 11 October. Summer temperatures in the upper layers were unusually low, the surface maximum of  $14.92^{\circ} C.$  being recorded on 14 September. The observations for 11 August and 14 September are given in full in Table I, from which it may be seen that marked temperature increases took place. Those in the deeper water are larger than in the upper layers and cannot be put down to vertical mixing. The sharpness of the thermocline remains unimpaired. A small but significant increase in salinity occurred. The weather records from Mount Batten Station show that mean air temperatures (at Plymouth) in the interval lay between the sea surface temperatures at E1 observed on 11 August and 14 September, and that hours of sunshine were a little less than average. Although direct absorption of solar radiation causes some warming of the sea surface irrespective of the temperature of the air, it is improbable that the observed rises in temperature throughout the water column could have occurred locally. The change therefore must have been caused by a displacement of water masses on a considerable scale.

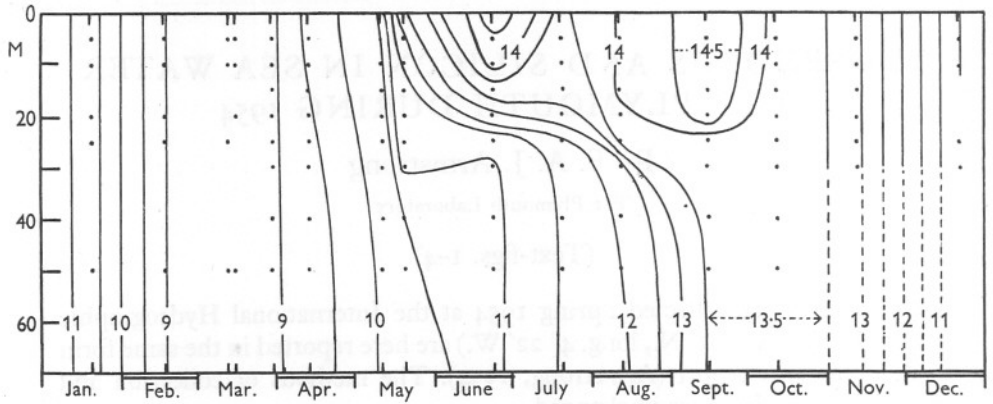


Fig. 1. Vertical temperature distribution at International Hydrographic Station E1, 1954. Contour lines at  $0.5^{\circ}\text{C}$  intervals.

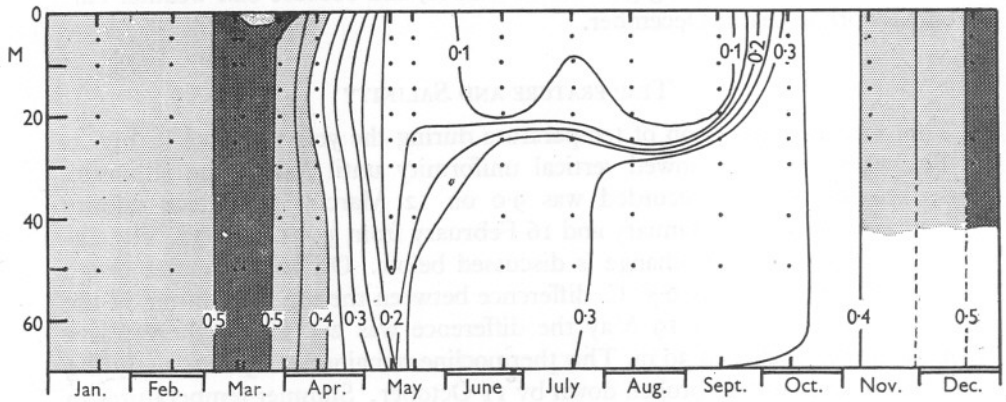


Fig. 2. Vertical distribution of phosphate as  $\mu\text{g atom P/l.}$  at International Hydrographic Station E1, 1954. Contour lines at  $0.05 \mu\text{g atom P/l.}$  intervals.

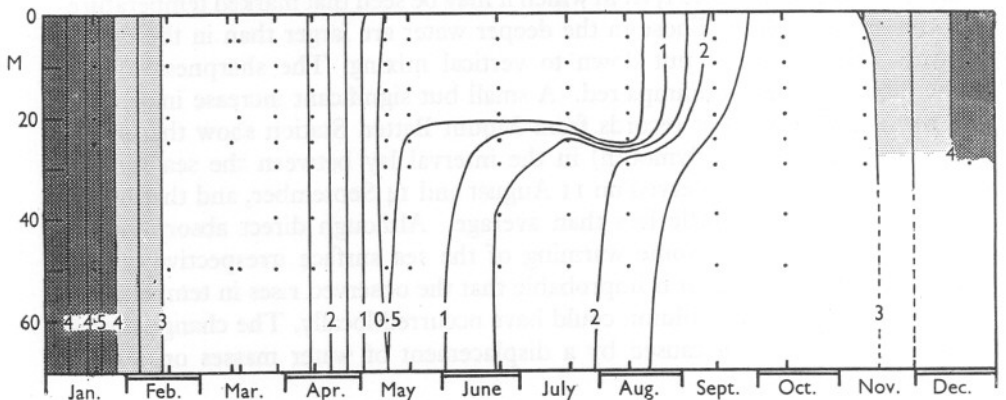


Fig. 3. Vertical distribution of silicate as  $\mu\text{g atom Si/l.}$  at International Hydrographic Station E1, 1954. Contour lines at  $0.5 \mu\text{g atom Si/l.}$  intervals.

During the whole of this period of 34 days a weak south-westerly air stream flowed over the area, becoming a strong south-westerly breeze (18–26 knots) for 2 days on 9–10 September. The weather remained cool and remarkably equable. The mean temperatures with standard deviations were

Max. day temp.	$17.3 \pm 1.3^{\circ} \text{C}$
Min. night temp.	$12.0 \pm 2.0^{\circ} \text{C}$
Overall mean	$14.7^{\circ} \text{C}$

Mean hours of sunshine were 5.46 h/day. The average for this period is estimated as about 5.9.

After the breakdown of the thermocline, temperatures decreased as is normal. On 21 December the upper 10 m. was colder and less saline than at 25 and 30 m (e.g. 5 m  $10.48^{\circ} \text{C}$ ,  $34.76\text{‰}$  S; 25 m  $11.07^{\circ} \text{C}$ ,  $35.10\text{‰}$  S) which suggests the presence of coastal water after the heavy rainfall of late November and early December.

TABLE I. TEMPERATURE AND SALINITY AT INTERNATIONAL HYDROGRAPHIC STATION E1, 11 AUGUST AND 14 SEPTEMBER 1954

Depth (m)	Temperature ( $^{\circ} \text{C}$ )		Salinity ( $\text{‰}$ )	
	11 Aug.	14 Sept.	11 Aug.	14 Sept.
0.5	14.05	14.92	35.24	35.25
5	14.05	14.87	35.21	35.25
10	14.05	14.87	35.24	35.27
15	14.03	14.87	35.24	35.27
20	13.99	14.77	35.25	35.27
25	13.98	13.70	35.25	35.30
30	12.38	13.59	35.29	35.35
40	12.22	13.57	35.30	35.35
50	12.00	13.54	35.29	35.35
70	11.91	13.53	35.33	35.33

#### PHOSPHATE

The vertical distribution of phosphate is shown in Fig. 2, and values at 10 and 50 m in Fig. 4. The water column was vertically almost homogeneous until early May. There was no significant change between 19 January and 16 February. During April phosphate concentrations fell sharply, and on 10 May were low throughout the water column. It is reasonable to assume that the vertical mixing possible before the establishment of the thermocline had carried part of the phytoplankton crop below the photosynthetic zone. After 19 May when the thermocline restricted vertical movement of water, this part of the phytoplankton would be trapped at depths where it could not long survive for lack of light. The consequence is interesting. Above the thermocline phosphate remained low (minimum  $0.07 \mu\text{g}$  atom P/l. on 11 August), but at deeper levels it increased, presumably by regeneration from the dying phytoplankton.

By 11 October, when the water had become isothermal, phosphate also became uniform, and increased until the end of the year.

## SILICATE

The vertical distribution of silicate is shown in Fig. 3 and values at 10 and 50 m in Fig. 4.

On 19 January silicate was  $4.7 \mu\text{g atom Si/l.}$ , a little higher than in December 1953, and the highest value recorded here since the present series of observations began in 1950. On 16 February the concentration was  $2.8 \mu\text{g atom Si/l.}$

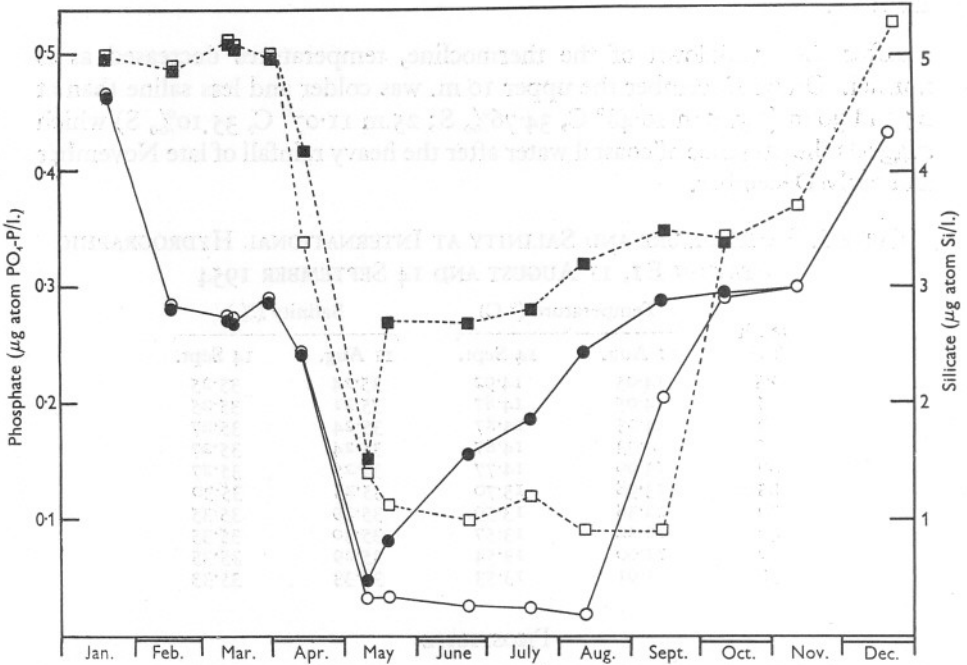


Fig. 4. Phosphate ( $\mu\text{g atom PO}_4\text{-P/l.}$ ) and silicate ( $\mu\text{g atom Si/l.}$ ) at 10 and 50 m at International Hydrographic Station E1 during 1954. Phosphate at 10 m,  $\square$ ; at 50 m,  $\blacksquare$ . Silicate at 10 m,  $\circ$ ; at 50 m,  $\bullet$ .

This very large decrease cannot have been caused by growth of diatoms. Such a growth would have been unprecedented at this time of the year, but is ruled out of account since there was no corresponding decrease in phosphate. The change in silicate must be ascribed to an influx of another body of water. There was, as noted above, a small change in salinity.

Silicate values fluctuated somewhat until 12 April, when the mean value was 2.5. On 10 May this had fallen to 0.4 when phosphate had also diminished throughout the water column. After the establishment of the thermocline, silicate remained low in the upper layers (minimum value  $0.17 \mu\text{g atom Si/l.}$  on 11 August) though not so low as in 1953. Below the thermocline there was a steady increase, more gradual than that for phosphate. The values at 50 m in

Fig. 4 show an almost linear increase with time, which suggests that silica was dissolving from the frustules of diatoms trapped and dying below the euphotic zone.

On 14 September silicate had risen to  $2.1 \mu\text{g}$  atom Si/l. in the upper layers, although phosphate remained low. The possibility that diatoms may have been supplanted by non-siliceous algae cannot be excluded, though without more knowledge of the flora at this station this is speculative. It seems certain, considering the marked temperature change and the appreciable alteration in salinity, that there was a change in the water mass. Silicate concentrations increased further in November and December and high values around  $4.3 \mu\text{g}$  atom Si/l. were found in the top 10 m layer on 21 December.

TABLE II. INTEGRAL MEAN CONCENTRATIONS IN WATER COLUMN AT STATION E I

Date	Phosphate-P ( $\mu\text{g}$ atom P/l.)	'Total-P' ( $\mu\text{g}$ atom P/l.)	Silicate ( $\mu\text{g}$ atom Si/l.)
19. i. 54	0.50	0.57	4.70
16. ii. 54	0.49	0.61	2.83
12. iii. 54	0.51	0.61	2.74
15. iii. 54	0.51	0.62	2.62
29. iii. 54	0.49	0.62	2.88
12. iv. 54	0.41	0.61	2.47
10. v. 54	0.14	0.40	0.39
19. v. 54	0.19	0.36	0.63
22. vi. 54	0.21	0.37	1.10
19. vii. 54	0.23	0.41	1.32
11. viii. 54	0.24	0.45	1.54
14. ix. 54	0.26	0.44	2.61
11. x. 54	0.34	0.46	2.95
11. xi. 54	0.41*	0.55*	2.94*
21. xii. 54	0.53*	0.64†	3.71†

\* Upper 30 m only. † Upper 25 m only.

#### INTEGRAL MEAN CONCENTRATIONS

Computed figures are shown in Table II, and need little comment. The decreases representing consumption of nutrients in the spring outburst of plants were: phosphate  $0.37 \mu\text{g}$  atom P/l., total phosphorus  $0.26 \mu\text{g}$  atom P/l., silicate  $2.49 \mu\text{g}$  atom Si/l.

#### SUMMARY

The results of analyses of water from the International Hydrographic Station E I during 1954 are discussed. The seasonal variation is shown, in which it appears that consumption of nutrients in the spring outburst of plants was: phosphate  $0.37 \mu\text{g}$  atom P/l., total phosphorus  $0.26 \mu\text{g}$  atom P/l., silicate  $2.49 \mu\text{g}$  atom Si/l., these figures being means for the whole water column. Unusual changes in silicate concentrations between January and February,

and between August and September, are ascribed to changes in the water mass at the station. This conclusion is supported by the temperature, salinity and phosphate observations.

REFERENCE

ARMSTRONG, F. A. J., 1954. Phosphorus and silicon in sea water off Plymouth during the years 1950 to 1953. *J. Mar. biol. Ass. U.K.*, Vol. 33, pp. 381-92.

SEA WATER CONCENTRATIONS IN WATER COLUMN  
AT STATION 14

Date	Depth (m)	Phosphate (μg/l)	Silicate (μg/l)
1950.7.22	0	0.10	0.25
1950.7.22	10	0.10	0.25
1950.7.22	20	0.10	0.25
1950.7.22	30	0.10	0.25
1950.7.22	40	0.10	0.25
1950.7.22	50	0.10	0.25
1950.7.22	60	0.10	0.25
1950.7.22	70	0.10	0.25
1950.7.22	80	0.10	0.25
1950.7.22	90	0.10	0.25
1950.7.22	100	0.10	0.25
1950.7.22	110	0.10	0.25
1950.7.22	120	0.10	0.25
1950.7.22	130	0.10	0.25
1950.7.22	140	0.10	0.25
1950.7.22	150	0.10	0.25
1950.7.22	160	0.10	0.25
1950.7.22	170	0.10	0.25
1950.7.22	180	0.10	0.25
1950.7.22	190	0.10	0.25
1950.7.22	200	0.10	0.25
1950.7.22	210	0.10	0.25
1950.7.22	220	0.10	0.25
1950.7.22	230	0.10	0.25
1950.7.22	240	0.10	0.25
1950.7.22	250	0.10	0.25

... in Table II and are not included in the present paper. The data presented in this paper are the only data available for the period 1950-1953. The phosphate concentrations are given in μg/l and the silicate concentrations in μg/l. The data show that the concentrations of both phosphate and silicate are relatively constant throughout the water column and throughout the period of observation. This is in contrast to the results of other workers who have found that both phosphate and silicate concentrations are higher in the surface water and lower in the bottom water. The results of this study suggest that the water mass at Station 14 is well mixed and that there is no significant vertical or horizontal stratification of phosphate and silicate concentrations.