Influence of clay in suspension on phytoplankton production in the Ria of Vigo

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The main factors influencing phytoplankton production are: concentration of nutrients, light and temperature. Nutrients are not usually a limiting factor of production in the inner part of the Ria of Vigo since their concentration is high enough, nearly all the year, and temperature does not drop below 12 ºC even in winter. The most important factor is the amount of incident energy (Vives and Fraga, 1961), specially its penetration in the water.

During recent years a decrease in the transparency of the sea has been observed. In order to have a quantitative estimation of this pernicious effect, five stations have been studied in the middle part of the Ria of Vigo during one year.

Material and methods

Normally the salinity in the Ria ranges from 33 to 36 ‰. Lower values are only found in surface water after sufficiently intense rain to reduce the salinity to 26 ‰ in the surface water.

Measurements and samples were made in the five stations indicated in fig. 1, where samples were collected at 0, 2, 5, 10 and 20 m depth to determine salinity. Temperature was measured with a bathythermograph.

Transparency of the water.- This was measured with a white Secchi disc, 30 cm diameter.

Chlorophylls.- At each station a representative sample was taken of the complete water column, from the surface to the Secchi disc visibility and 3 litres of this sample were filtered to determine chlorophylls according to the method described by UNESCO (1966), the estimation being made using the equations given in the same publication.

The carotenes value was estimated according to Richards and Thompson equations (1952) after chlorophyll correction had been made.

Clay.- One litre of water, from the same sample used in chlorophyll determination, was filtered through a "Millipore HA" filter of cellulose ester, 0.45 um pore size and 25 mm diameter. The residue was slowly washed with 20 ml of distilled water. Afterwards the upper part of the glass filtering device was removed and the filter edge washed with 2 ml of water with suction. This last operation is essential in order to get low and repeatable blanks. Then, the filter together with the washed residue, was carbonised at 200 ºC, for an hour, in a covered crucible and then it was calcined at 570 ºC for another hour. The weight was taken on a semi-micro balance. The filters used in this operation gave a blank of 0.015 mg/filter.

Relation between Secchi disc visibility, chlorophyll and clay

The relation between vertical attenuation of the light and Secchi disc visibility is given by

$$\frac{1.64}{S} = C \qquad (I) \qquad \text{where} \quad C = \frac{1}{D} \log_{10} \frac{F_o}{F_D}$$

S, is the Secchi disc visibility in metres; C, the vertical attenuation coefficient; F_o the radiant flux of the light entering the water surface and F_D the flux at a depth D in metres.

On the other hand, attenuation of the light in the sea is due to the absortivity and scattering produced by phytoplanktonic cells, suspended particles and absortivity of water itself, and the vertical attenuation coefficient is the sum of the coefficient of each factor

$$C = C_1 + C_2 \text{ Chl } \underline{a} + C_3 \text{ clay} \qquad (II)$$

C_1, absorbance of water coefficient per metre; C_2, attenuation coefficient of phytoplankton and C_3 attenuation coefficient of clay.

Therefore

$$\frac{1.64}{S} = C_1 + C_2 \text{ Chl } \underline{a} + C_3 \text{ clay}$$

With experimental data from five stations a multiple correlation was made, obtaining:

Station 1	$1/S = 0.61(0.11 + 0.027 \text{ Chl } \underline{a} + 0.18 \text{ clay})$	n=27	R = 0.36
Station 2	$1/S = 0.61(0.13 + 0.018 \text{ Chl } \underline{a} + 0.21 \text{ clay})$	n=26	R = 0.78
Station 3	$1/S = 0.61(0.14 + 0.022 \text{ Chl } \underline{a} + 0.15 \text{ clay})$	n=27	R = 0.59
Station 4	$1/S = 0.61(0.08 + 0.021 \text{ Chl } \underline{a} + 0.27 \text{ clay})$	n=28	R = 0.63
Station 5	$1/S = 0.61(0.08 + 0.009 \text{ Chl } \underline{a} + 0.31 \text{ clay})$	n=27	R = 0.72
Total	$1/S = 0.61(0.11 + 0.019 \text{ Chl } \underline{a} + 0.21 \text{ clay})$	n=135	R = 0.63

(III)

S, in metres; Chl a in ug/l and clay in mg/l; n, number of observations; R, multiple correlation coefficient.

$C_1 = 0.11$ is the water absortivity in the Ría after supressing all the particulate matter, phytoplankton and clay, being the sum of water absorbance (oceanic water 0.026), plus the dissolved stable coloured organic substances absorbance. The labile coloured substances of phytoplankton origin have the same variations, therefore their absorbance will be reflected in the term C_2.

It must be taken into account that the constant multiplying weight of Chl a, 0.019, in formula (III), does not represent the vertical attenuation coefficient of phytoplankton as can be observed below.

The attenuation coefficient produced by the particulate matter scattering 0.21 mg/l, found here, coincides with those given by Joseph (1953) and Jones and Wills (1956), but there is some discrepancy with other authors. This may be ributed to size of particles. For the same weight of a determined particulate matter, the scattering coefficient is inversely proportional to the diameter of particles, which can vary greatly;

Diatom silica correction in the equation of light attenuation

The analytical method used to determine the clay values also includes the silica of diatom frustules. For this reason the real weight of clay is the weight of particulate mineral matter (PMM) minus the weight of diatom silica (Sil)

i.e. $$\frac{1.64}{S} = C_1 + C_2 \text{ Chl } \underline{a} + C_3 \text{ (PMM - Sil)}$$

At the same time silica quantity is a function of chlorophyll a. The phytoplankton of the Ría has a mean annual proportion diatoms/dinoflagellate of 78 % and 22% (in chlorophyll a). It is obtained, Sil = 0.062 Chl a if the relation of diatoms/dinoflagellate is as pointed out, and assuming that mg SiO_2/ug Chl a = 0.08 for diatoms.

The former equation becomes

$$\frac{1.64}{S} = C_1 + (C_2 - 0.062\ C_3)\ \text{Chl}\ a + C_3\ \text{PMM}$$

For that reason the factor for chlorophyll a, 0.019 in equation (III), is not the attenuation coefficient of phytoplankton C_2, but this can be estimated since C_3 is already known, its value being 0.032.

In fact the relation diatom/dinoflagellate varies greatly, either in populations only constituted by diatoms such as spring bloom or dinoflagellate populations as red tide. Therefore, 0.062 is not constant but a function of diatom proportion in phytoplankton. That is why it is intended to introduce a correction. In that case it would be necessary to know beforehand the quantity of diatoms by counting them in the microscope. As it was not possible to do that, the carotene concentration was used, accepting that the relation carotenes/chlorophyll a in diatoms is different from that of dinoflagellate.

Introducing this correction, a lineal relation between Chl a, PMM and carotenes is obtained, but it has been found that carotenes are a function of Chlorophyll a (correlation coefficient 0.95), this is why the use of this new variable provides none information. Therefore, the new equation does not improve the adjustment.

Decrease of primary production by attenuation of the light due to the presence of light

It was formerly pointed out that the main limiting factor of phytoplanktonic production in the Ría of Vigo is lack of light.

According to equations given by various authors to estimate the total photosynthesis in the euphotic zone, it is concluded that if the distribution of nutrients and chlorophyll in the euphotic zone is uniform, and incident energy passing the surface does not vary, primary production is inversely proportional to the attenuation coefficient of the water and is, therefore directly proportional to the Secchi depth.

For this reason, in order to calculate the annual relation between real production and the production in the case where clay does not exist, S value is estimated from the mean values of clay and chlorophyll given in table I and the same value if clay does not exist.

Finally, when clay does not exist, ash weight is not zero, and it is necessary to take into account the weight of diatom silica which is: mg of silica = 0.062 . ug/Chl a, that is, 0.18 mg/l as formerly estimated.

Thus one obtains, in this way, a relation P/P' = 0.78, that is, a primary production 78 % of that estimated in the situation where there is no clay in suspension. Therefore, production decreases by about 22%.

TABLE I.- Annual mean values and extreme values of each variable in the five stations indicated in the map, fig. 1, and annual mean value for the whole zone

Stations	St-1	St-2	St-3	St-4	St-5	Total
Number of samples	27	26	27	28	27	135
Secchi m	7.00 3.3-11.4	6.34 2.5-10.0	6.46 3.1-12.0	7.25 2.8-14.1	7.48 3.4-12.9	6.964
1/Secchi	0.159 0.30-0.088	0.182 0.40-0.100	0.165 0.32-0.083	0.155 0.36-0.071	0.145 0.29-0.078	0.1612
Clay mg/l	0.460 0.01-0.82	0.500 0.06-1.00	0.467 0.12-0.79	0.446 0.07-0.79	0.436 0.19-0.74	0.4616
Chlorophyll a ug/l	2.56 0.32-8.45	3.41 0.34-18.55	2.80 0.31-10.42	2.72 0.20-11.37	2.85 0.36-14.17	2.863

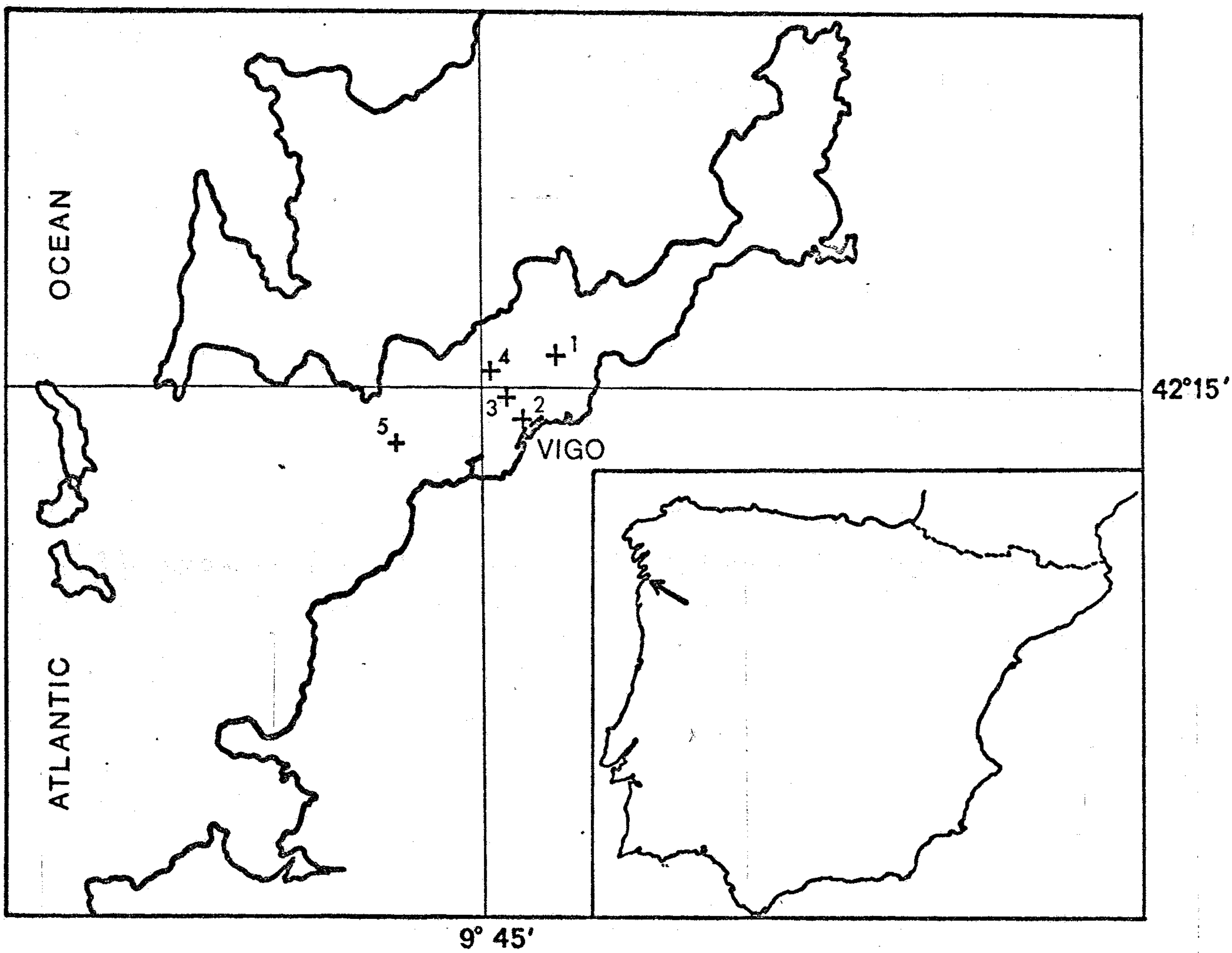

Fig. 1. Situation of the five stations

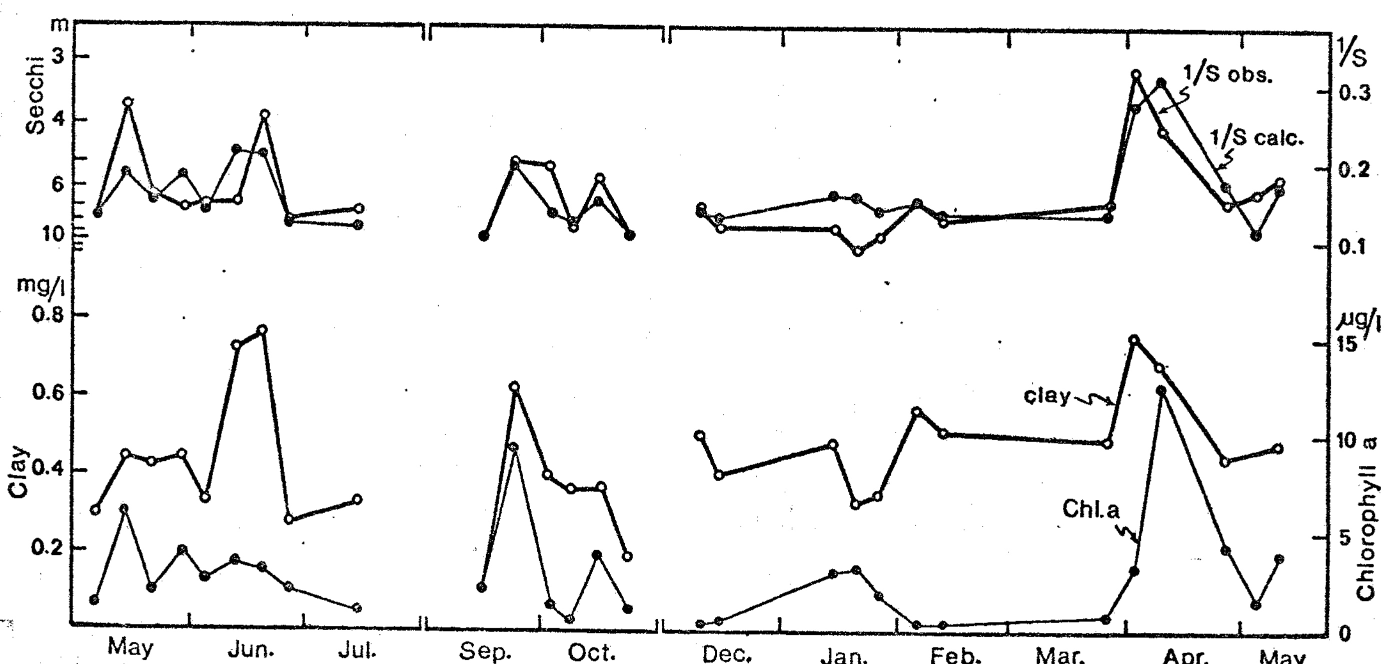

Fig. 2. Seasonal variation of clay and chlorophyll a concentrations, mean value of the five stations from the surface to Secchi disc visibility. Upper part: Inverse of Secchi depth, mean value of the five stations. Observed and estimated values.