Chapter VII

I. First trophic level

STUDY OF PHOTOSYNTHETIC PIGMENTS, PARTICULATE ORGANIC MATTER AND PHYTOPLANKTON WITHIN THE AREA DELIMITED BY THE MATHEMATICAL MODEL - NORTH SEA

by

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Introduction

Any biological system evolves with time. The study and understanding of such a system — especially if the interest is focused on the search of anomalies and irregularities — require a preliminary approach including the distribution of its elements and their proper variation. The amplitude and the rate of this variation is depending on the type of organisms, the period of the year and the environmental conditions.

The present quantitative and qualitative study on phytoplankton biomass (first trophic level) and particulate organic matter is based on one hand on the results obtained at four fixed stations and on the other hand on the analysis of all 25 stations of the area. This last study tends to be an approach to the understanding of the seasonal variations in the area under study.

1.- Study of the phytoplankton biomass and particulate organic matter at four fixed stations

1.1.- Methods

The results obtained during the two last years 1972 and 1973 have shown appreciable differences not only between two consecutive cruises but also differences of the same order of magnitude between different stations during a same cruise. In order to interprete the differences in concentrations observed (phytoplankton, chlorophyll, particulate organic matter), it was consequently necessary to reduce the time scale with the aim to get a better knowledge of the variations size proper to those parameters.

Four fixed stations were investigated during January and June each representing a special zone of the model : one offshore station M14 and three coastal stations, M01, M16, M06, respectively in the South, in the North and in front of the estuary. This last one is submitted to the mixing of waters from different origins.

Investigations extended generally on 5 days and included :

- a daily sampling at the depth of 2 m .
- an examination of a 24 h cycle at the depth of 2 m , at the rate of one sample every two hours.
- a study of variations with depth. The three levels – surface, medium and bottom were chosen.

1.2.- Results

The daily variations observed on the samples taken within one week or sometimes two (station M14 in June) are generally not very significant compared to those observed at the same stations but at the different cruises. From figures 7.1 to 7.9 which show daily and seasonal variations for each of the four stations, we may deduce :

a) M14 : offshore station sampled in January and June (figs. 7.1, 7.2)

One observes at this point for all three parameters (phytoplankton cells – chlorophylls – particulate organic matters) disordered daily variations probably more due to the errors on the measure than to an effective variation in concentration. Observed quantities are as a matter

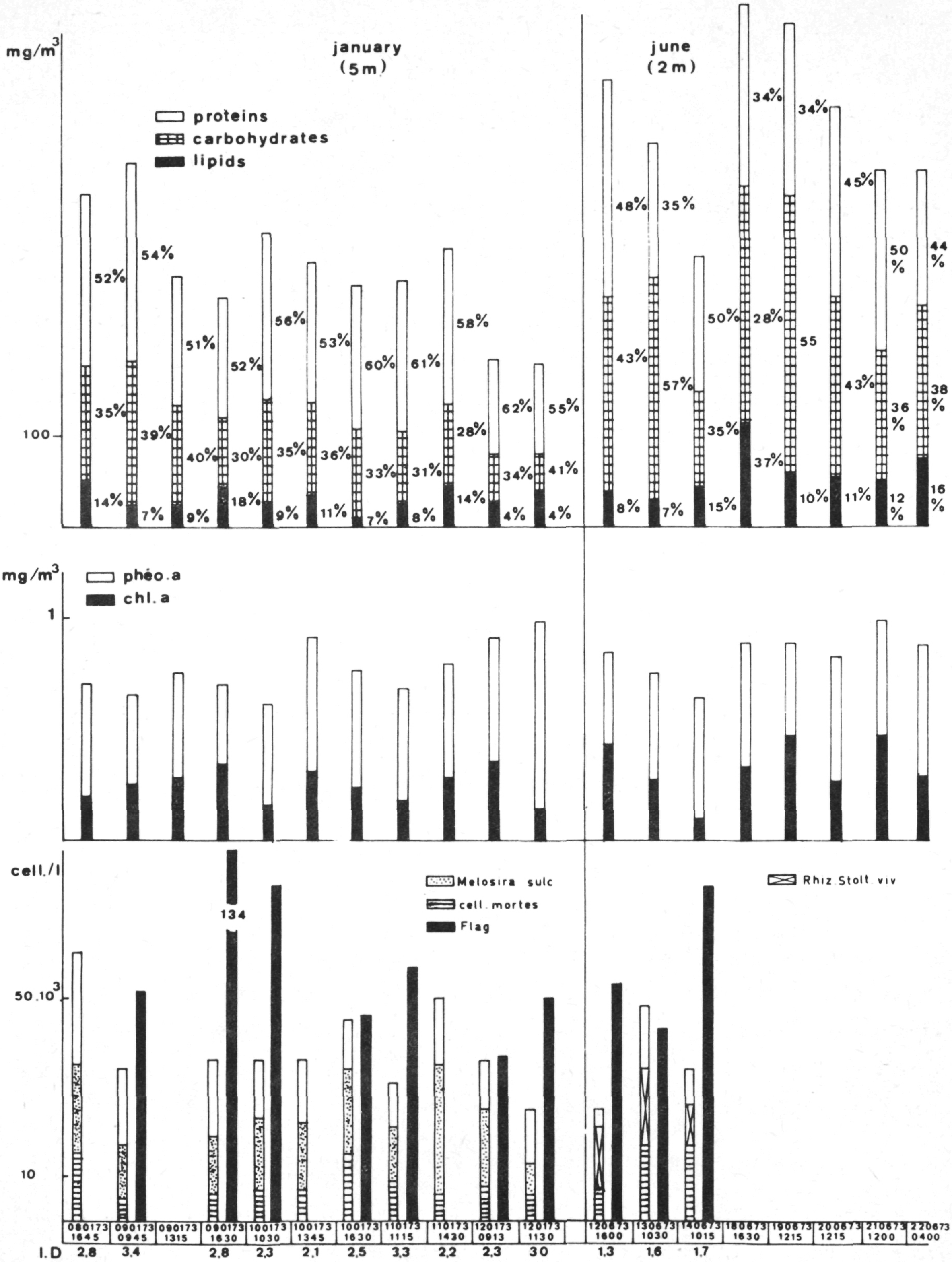


fig. 7.1.- Station M14, daily variations.

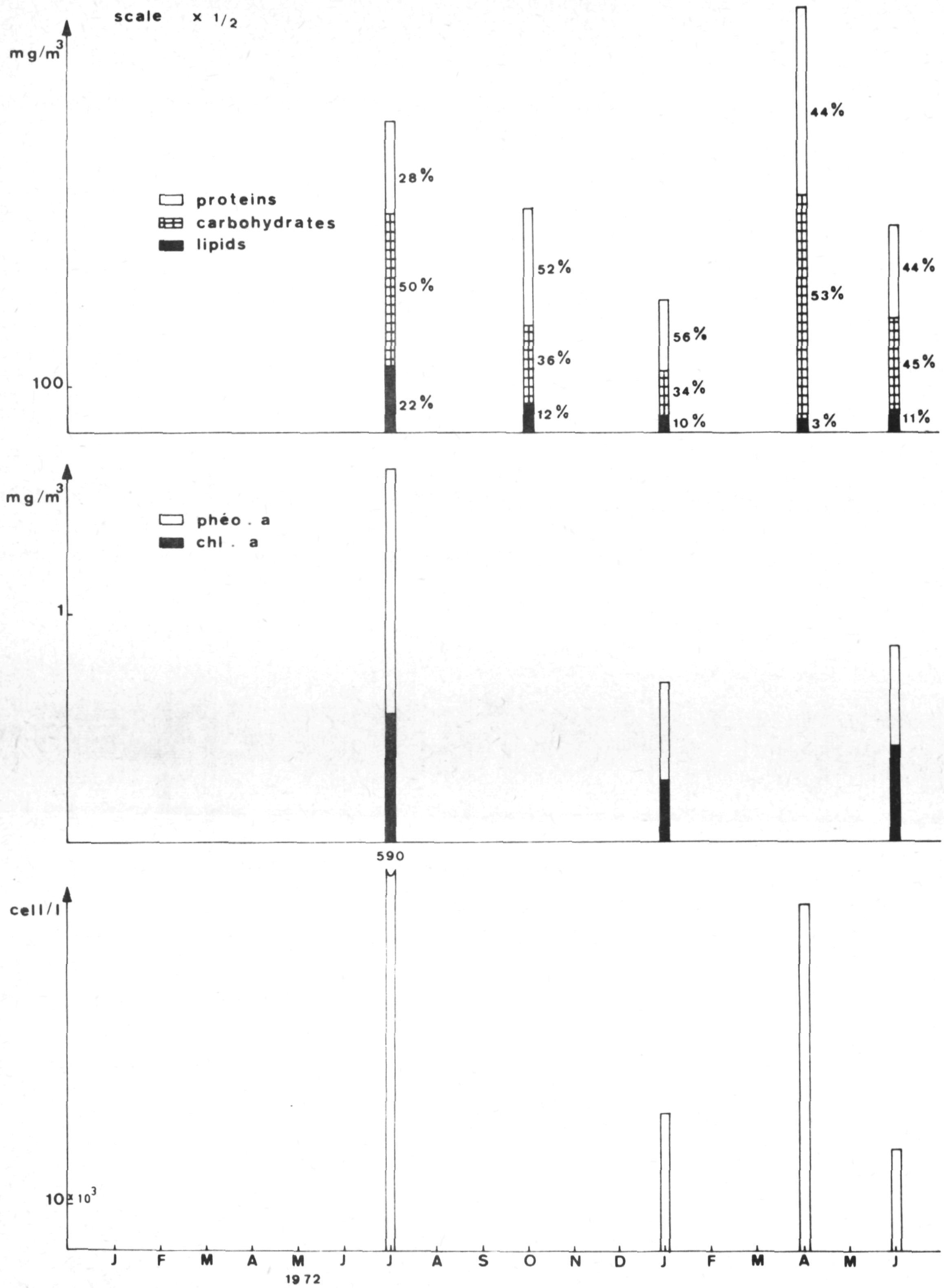


fig. 7.2.- Station M14, seasonal variations.

of fact very weak and lower than the sensitivity of the dosing and counting techniques.

In addition the comparison of the results obtained at this station at different times of the year, emphasizes the importance of detrital organic matter : for an equal quantity of pigments, larger quantities of particulate organic matter were observed in June than in January. We may deduce in the first case that the organic material is for a larger part composed by detritus (presence of dead cells). This assumption is enhanced by the study of detrital quality : variations in the ratios of the different metabolites (proteins — carbohydrates — lipids) are more important in June compared to those of January where the ratio Protein/Carbohydrate is always greater than 1 .

b) M01 : coastal station sampled in January

Considering the results reported on figures 7.3 and 7.4 it is to be observed from the quantitative point of view, that for none of the three parameters the daily fluctuations are important except for the sample of 24 January. In this last case, it is impossible to correlate the cell quantity nor with chlorophyll a, nor with particulate organic matter. This is perhaps to be linked to the important decrease of the species *Dimmerogramma minor*.

Considering now the qualitative aspect of the results, it must be pointed out that the heterogeneity in the qualitative distribution of particulate organic matter is linked to the coastal situation of the station and consequently to the tide.

Moreover, the quantity of particulate organic matter is large compared to the content in chlorophyll a and the pheo-pigments (degraded chlorophylls) are always more abundant than the active chlorophyll a . Both facts prove that this heterogeneity can be explained by a different detrital material.

c) M16 : coastal station sampled in May and in June (figs. 7.5, 7.6)

The results obtained on consecutive samples taken at the same hours (8 and 9 May, 12 h 30 and 26 and 27 June, 10 h) show a little increase of the phytoplankton biomass for all three parameters. This increase

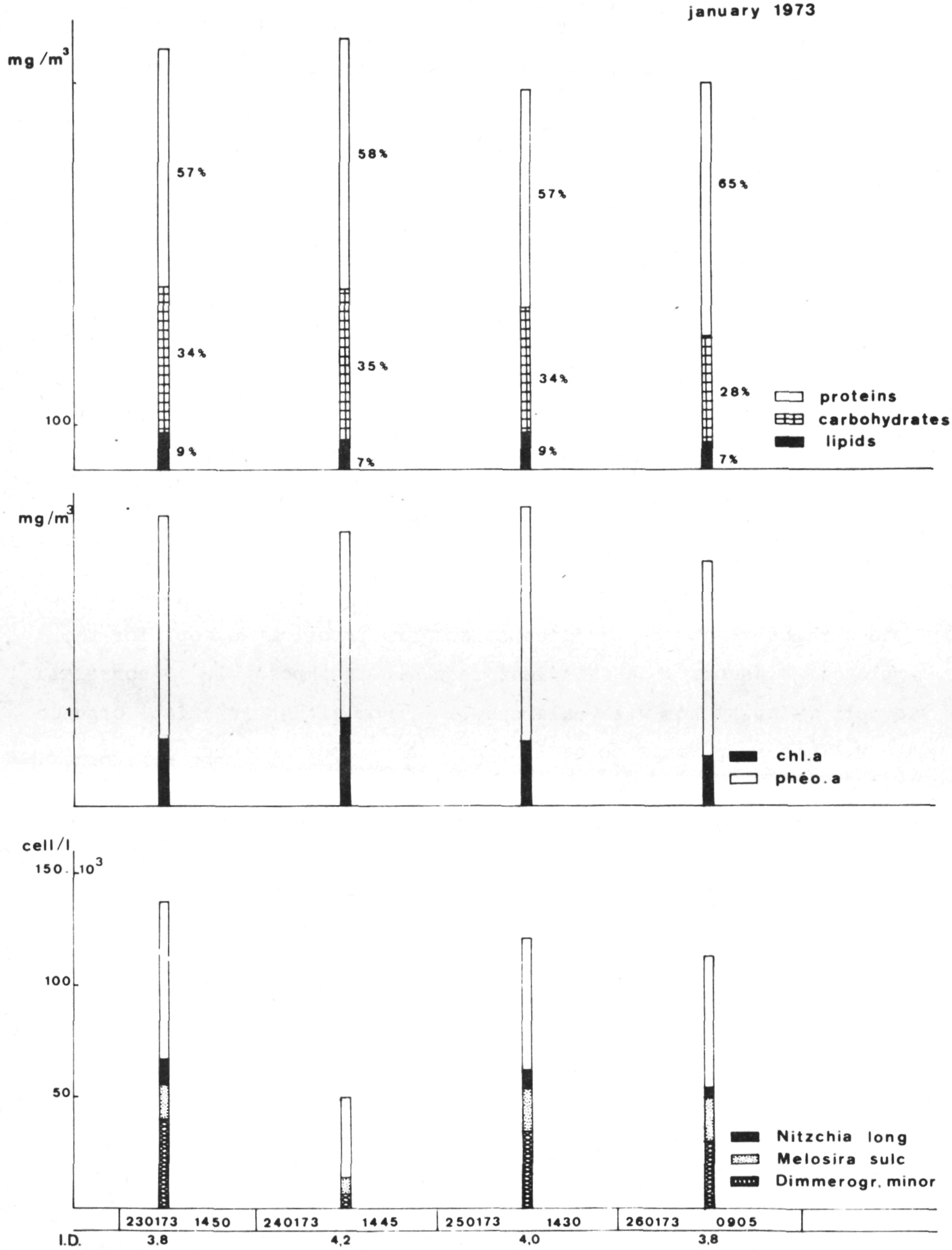


fig. 7.3.- Station M01, daily variations.

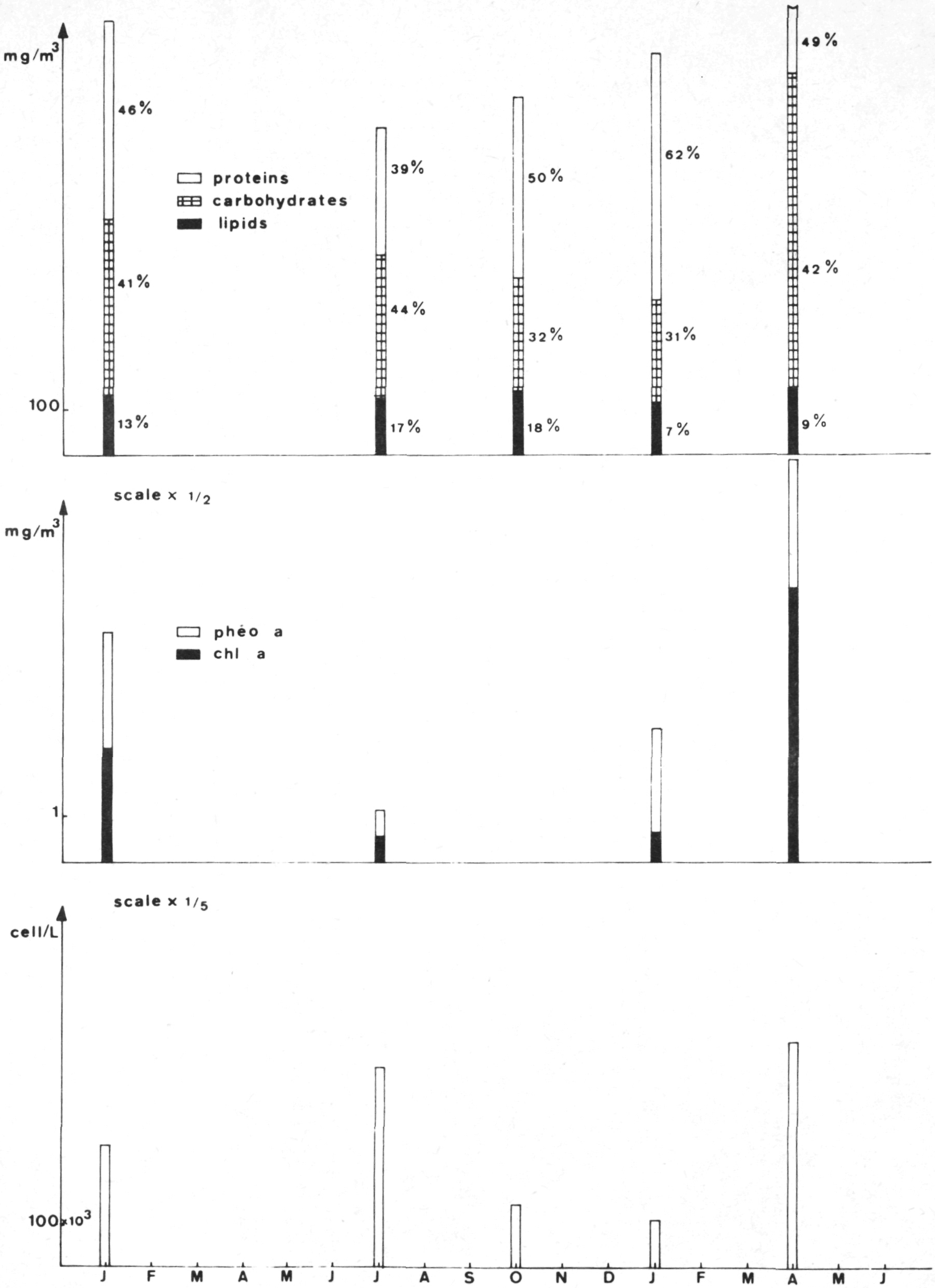


fig. 7.4.- Station M01, seasonal variations.

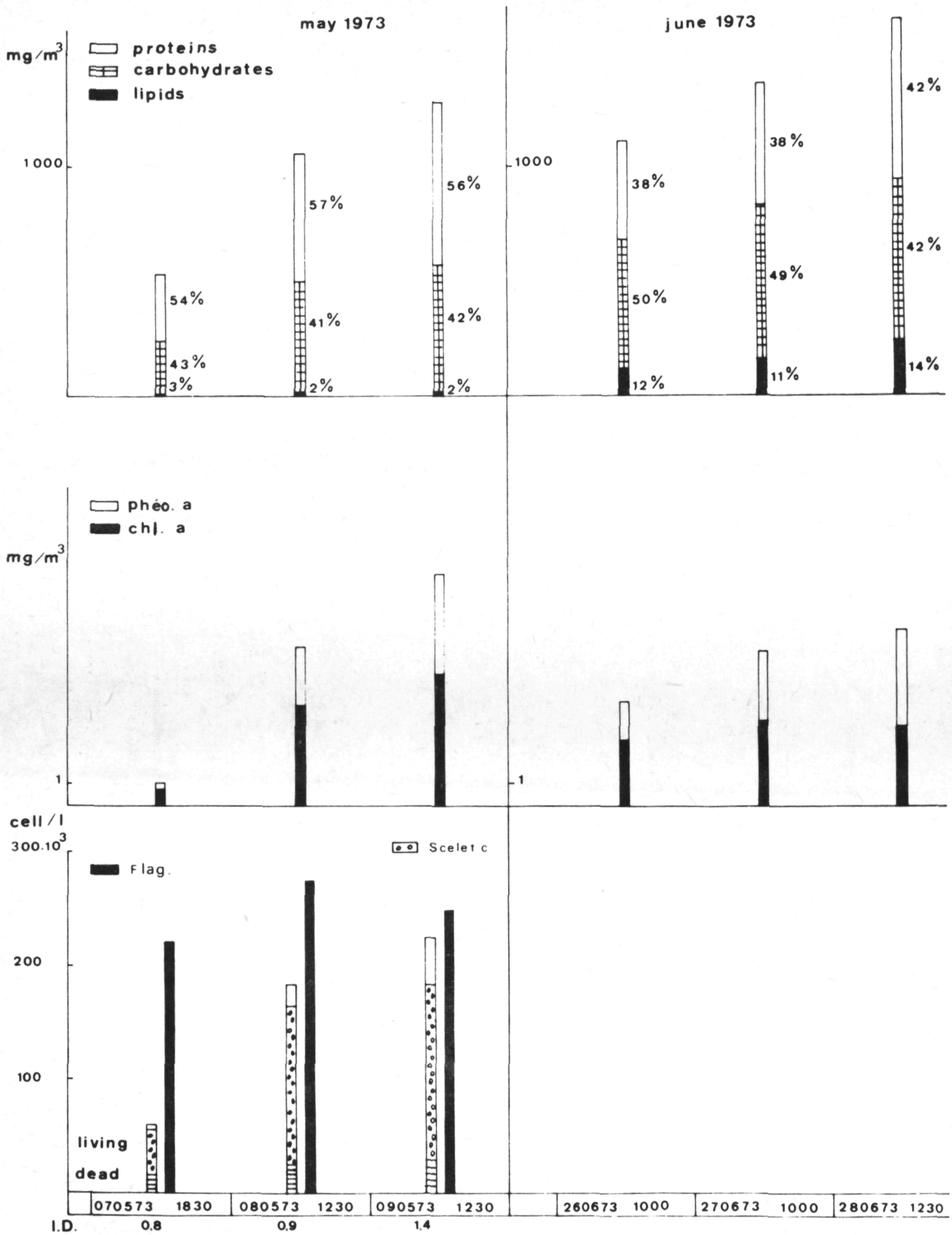


fig. 7.5.- Station M16, daily variations.

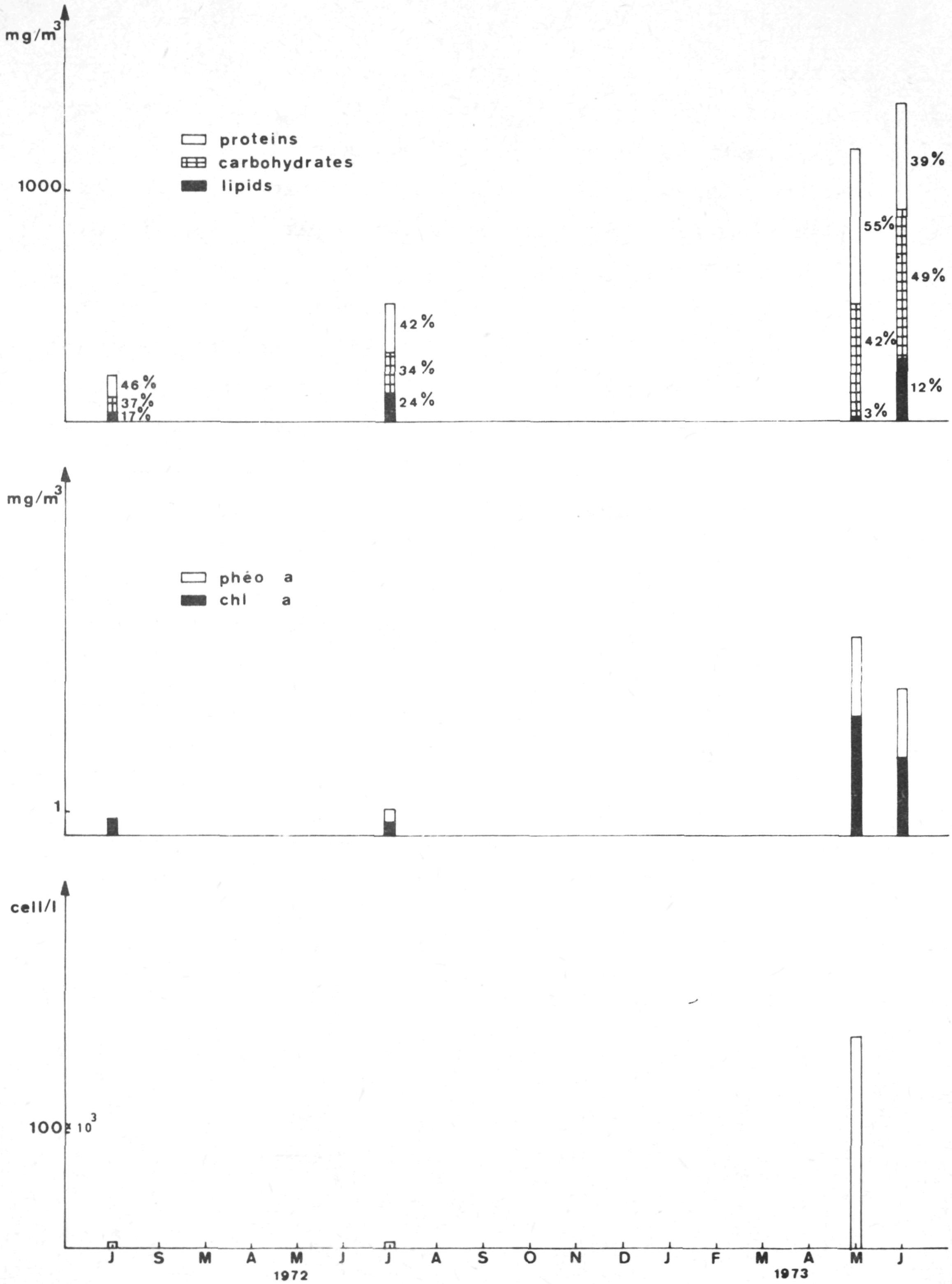


fig. 7.6.- Station M16, seasonal variations.

could correspond to the daily increment of the phytoplankton biomass (not consumed) resulting from the photosynthetic activity. However no conclusion may be drawn on the basis of only two consecutive samples.

In addition the analysis of the complete results point out important fluctuation of the biomass linked to the sampling time : 7 May 18h30, weak biomass; 8,9 May 12h30, high biomass.

The qualitative inventory of phytoplankton cells shows that the increase of biomass results essentially from an outburst of the spring species *Skeletonema costatum* whilst flagellates remain quite constant and always more abundant than diatoms.

Works on this subject [Lanskaya (1963)] mention indeed that the species *Skeletonema costatum* may contribute to fast variations of the biomass.

This statement may explain figure 7.7 showing a 24 h cycle of chlorophyll at the date of 8 May where a high biomass is recorded at 12h30 and a weak biomass at 18h30 .

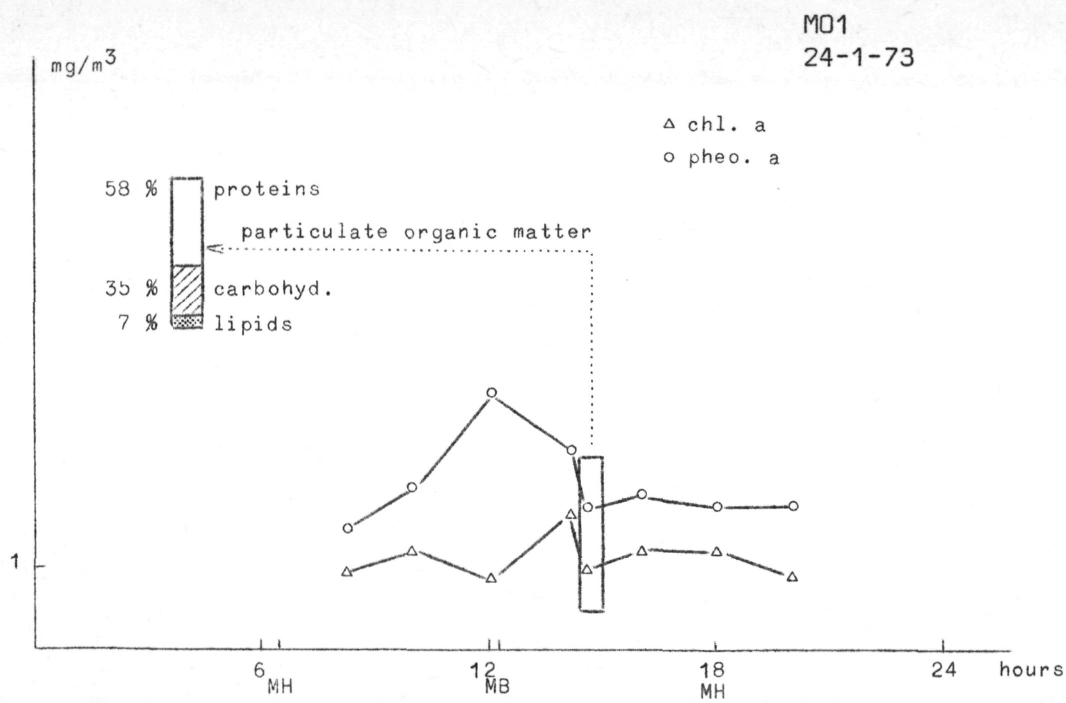


fig. 7.7a.- Fixed stations - 24 hours cycles.

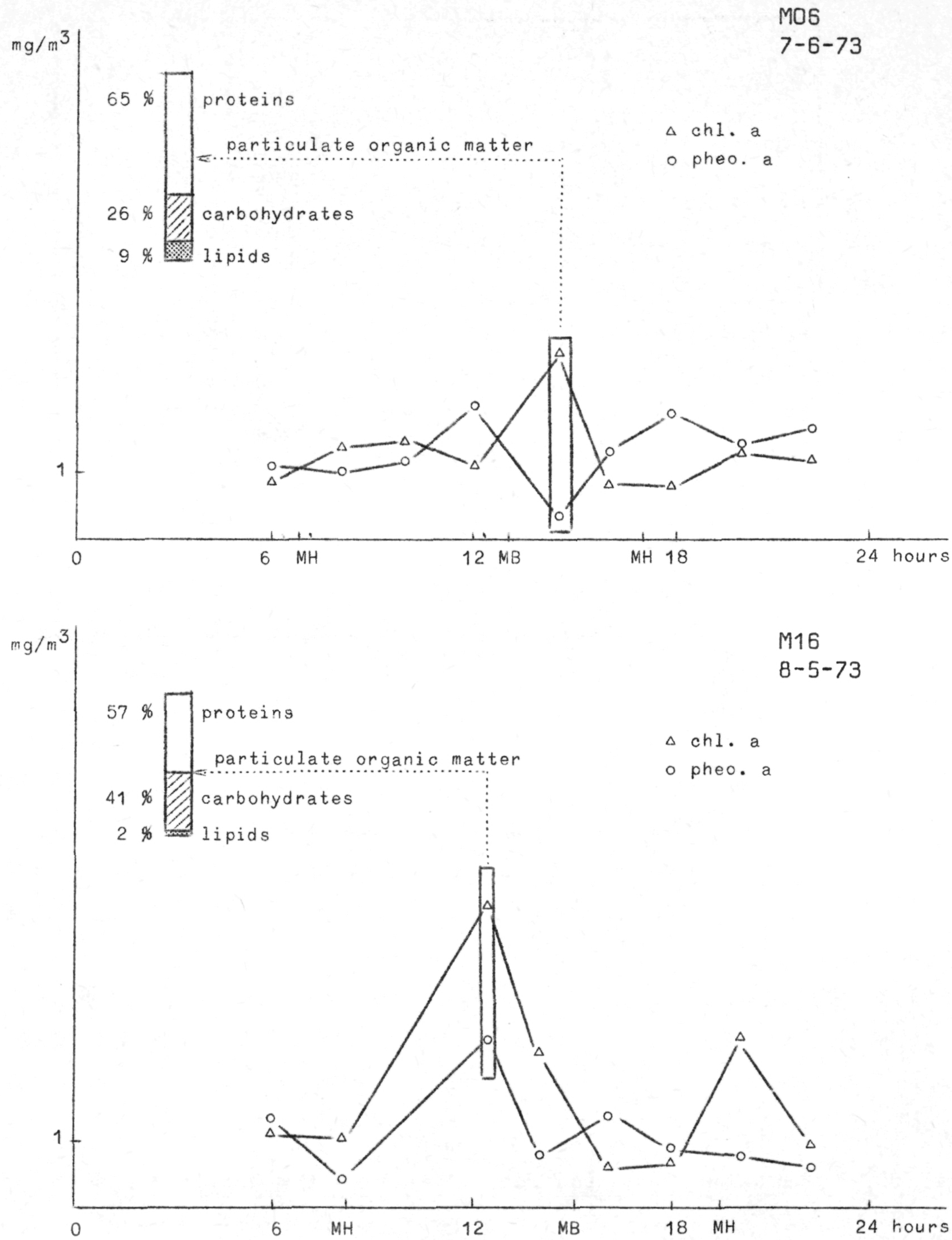


fig. 7.7b,c.- Fixed stations - 24 hours cycles.

Nevertheless, if the increase of the biomass is fast and selective and could be due to an endogenic rhythm of the species *Skeletonema costatum*, the fast decrease cannot be explained by a selective grazing of

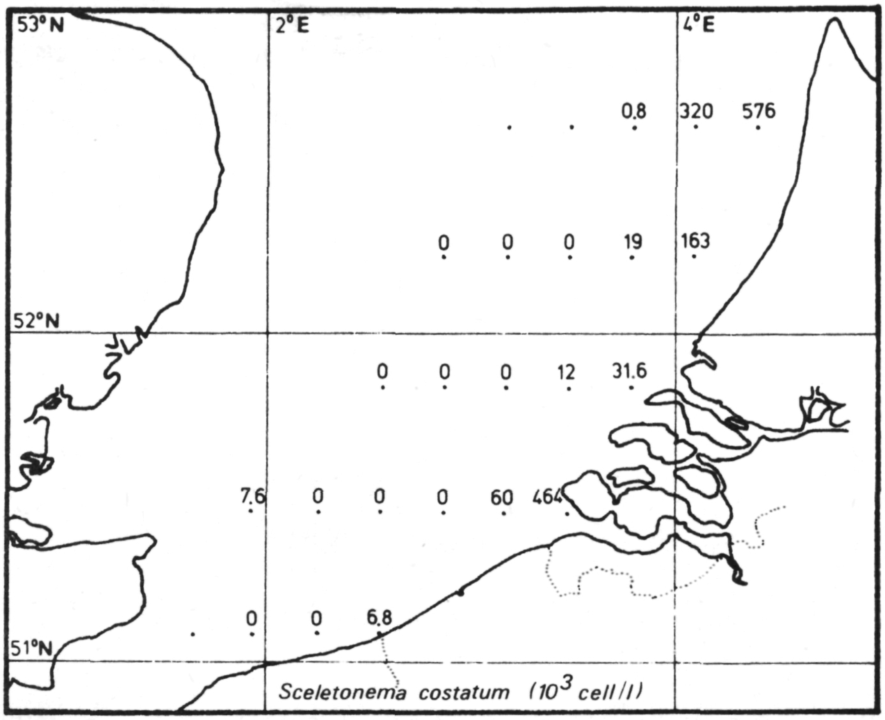


fig. 7.7d.

zooplankton {reference to the zooplankton results found in the Laboratory of Professor Polk [Daro-Bossicart : synthese 04 (1973)]}.

Consequently one can also assume that these spectacular variations of the phytoplankton biomass could be explained by the moving of waters. Refering to the map of distribution of the species *Skeletonema* during the cruise of April 1973 (figure 7.7d) the center of the bloom is indeed situated next to the stations M21, M22. The point M16 could therefore be more disturbed by fluctuations of the water mass because of its marginal position.

d) <u>M06 : coastal station in front of the estuary sampled in January and in June</u> (figs. 7.8, 7.9)

While the available energy flux (estimated by the particulate organic matter) do not present great seasonal variations, the fluctuations of the phytoplankton biomass (measured by chlorophyll and phytoplankton cells) are more pronounced :

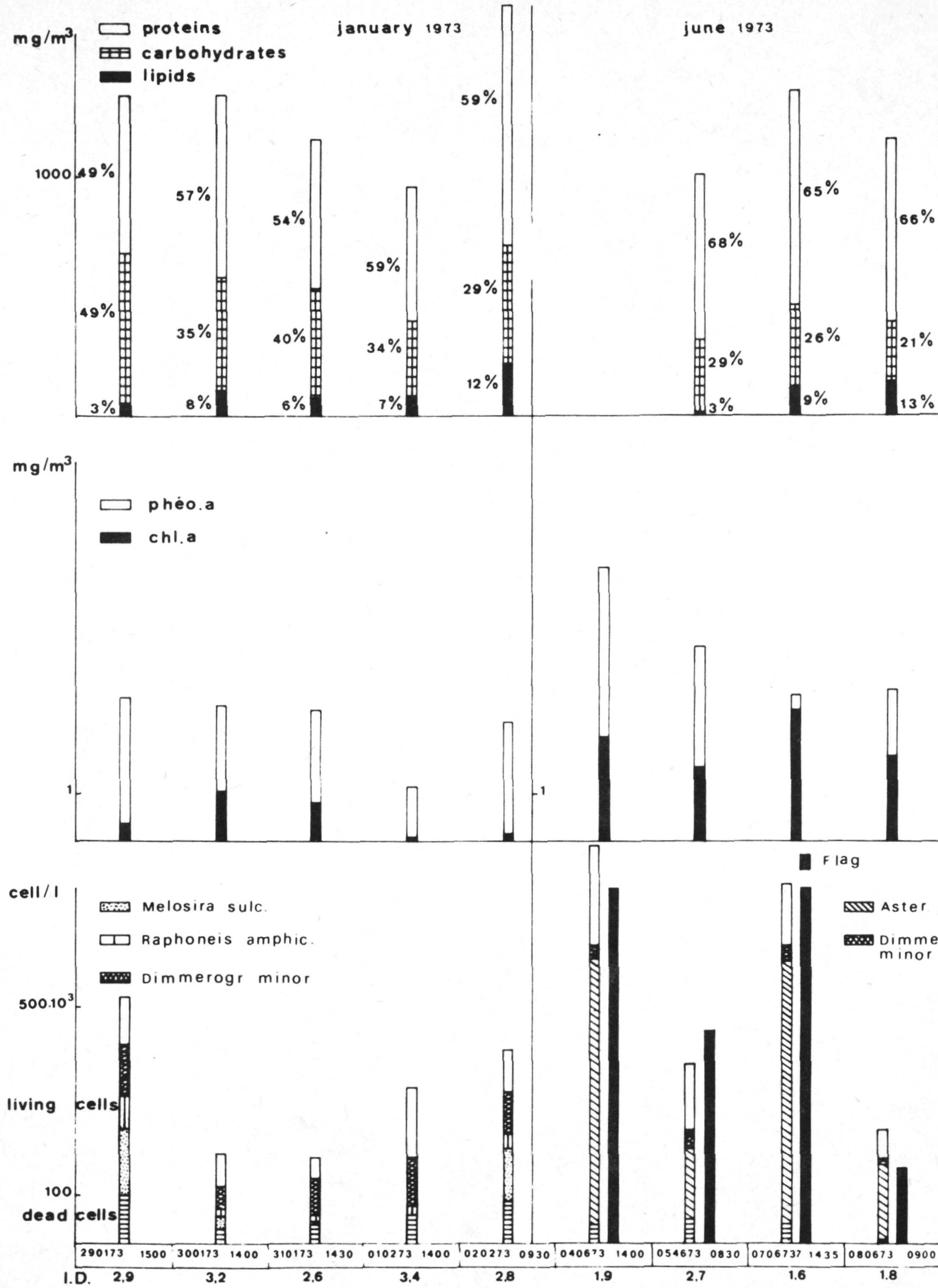


fig. 7.8.- Station M06, daily variations.

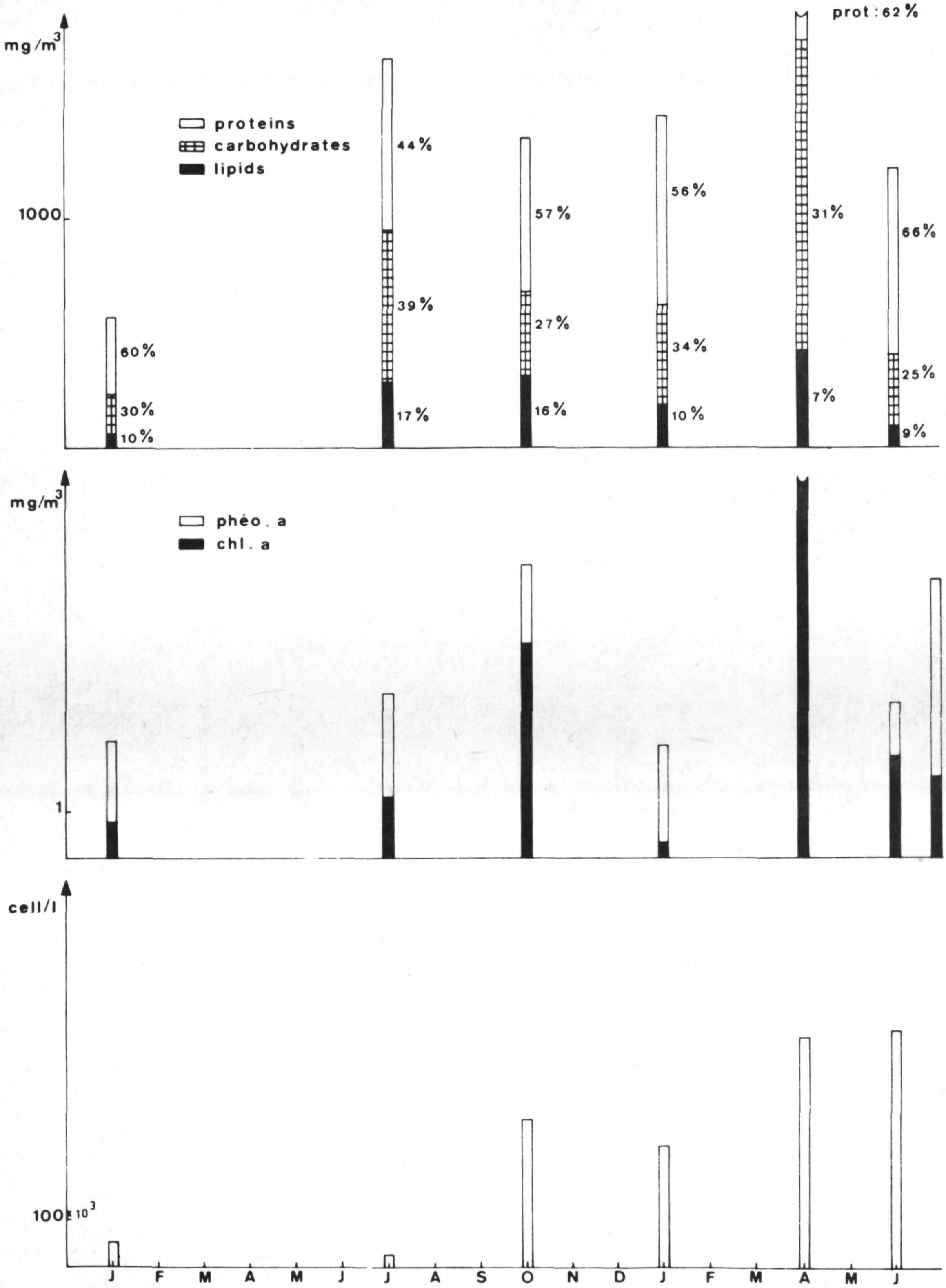


fig. 7.9.- Station M06, seasonal variations.

January

- Chlorophylls and phytoplankton cells are so weak that daily fluctuations are included in the error on the measure. In addition, many dead cells, an always greater quantity of degraded chlorophylls and large quantities of particulate organic matter associated with a weak content of chlorophyll a could represent an important drift of detritic material.

June

- Comparing only samples taken at the same hours, one records the same phenomenon than at station M16 in May : here biomass increase is due to the coastal diatom species *Asterionella Japonica*.

Located in front of the estuary station M06 undergoes the permanent stirring of different waters, but because no map of distribution of this species exists for the month of June in 1973, it is difficult to conclude to an effective bloom or to an arrival of water richer in *Asterionella*.

e) Vertical profiles (figs. 7.10, 7.11, 7.12, 7.13)

The study of variations with depth of photosynthetic pigments and particulate organic matter concerned stations M01 and M06 in April and June respectively. Results show larger quantities of pheopigments and particulate organic matter near the bottom.

This fact can correspond to a mixing of bottom sediments but can correspond as well with the Beklenishev's (1962) concept of detritus falling to the bottom mainly during periods of rapid phytoplankton growth when the zooplankton cannot assimilate all the plant cells. Stations M01 and M06 differ as following : the distribution of particulate organic matter with depth is identical to that of the pheo-pigments at station M01 while at station M06 it follows the distribution of the total amount of chlorophylls (living and degraded). It would mean that detritus are more considerable at station M01.

1.3.- Conclusions

While the daily variations for the quantitative and qualitative aspects are small, considering a period of five days, compared to the fluctuations observed at these same stations from one cruise to another, the study of a 24-hour cycle at stations M06 and M16 suggests that some

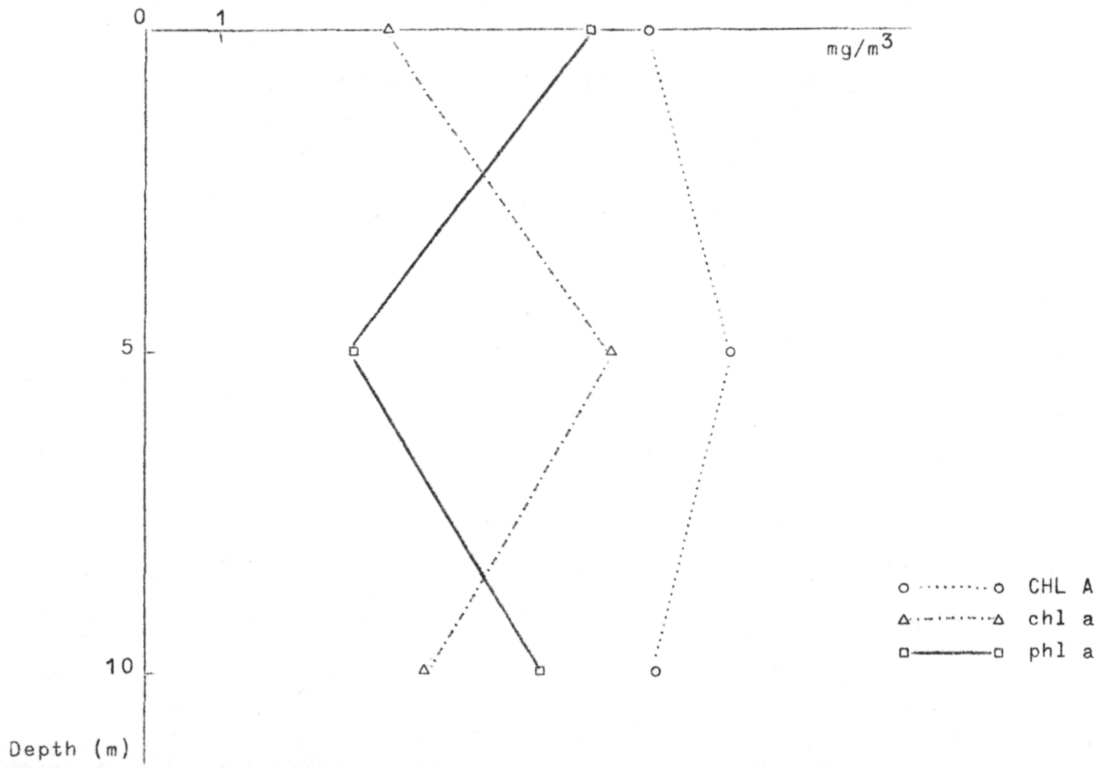


fig. 7.10.- Station M01 - Vertical profile.

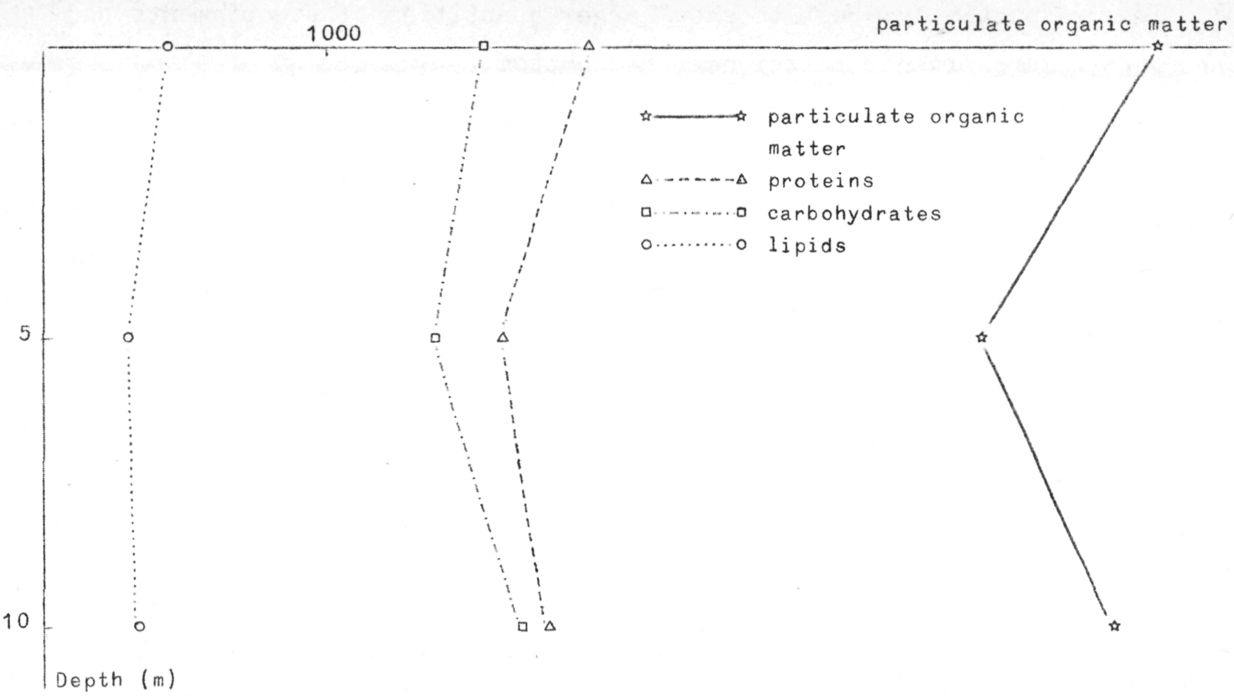


fig. 7.11.- Station M01 - Vertical profile.
18-4-73 13 h 30 .

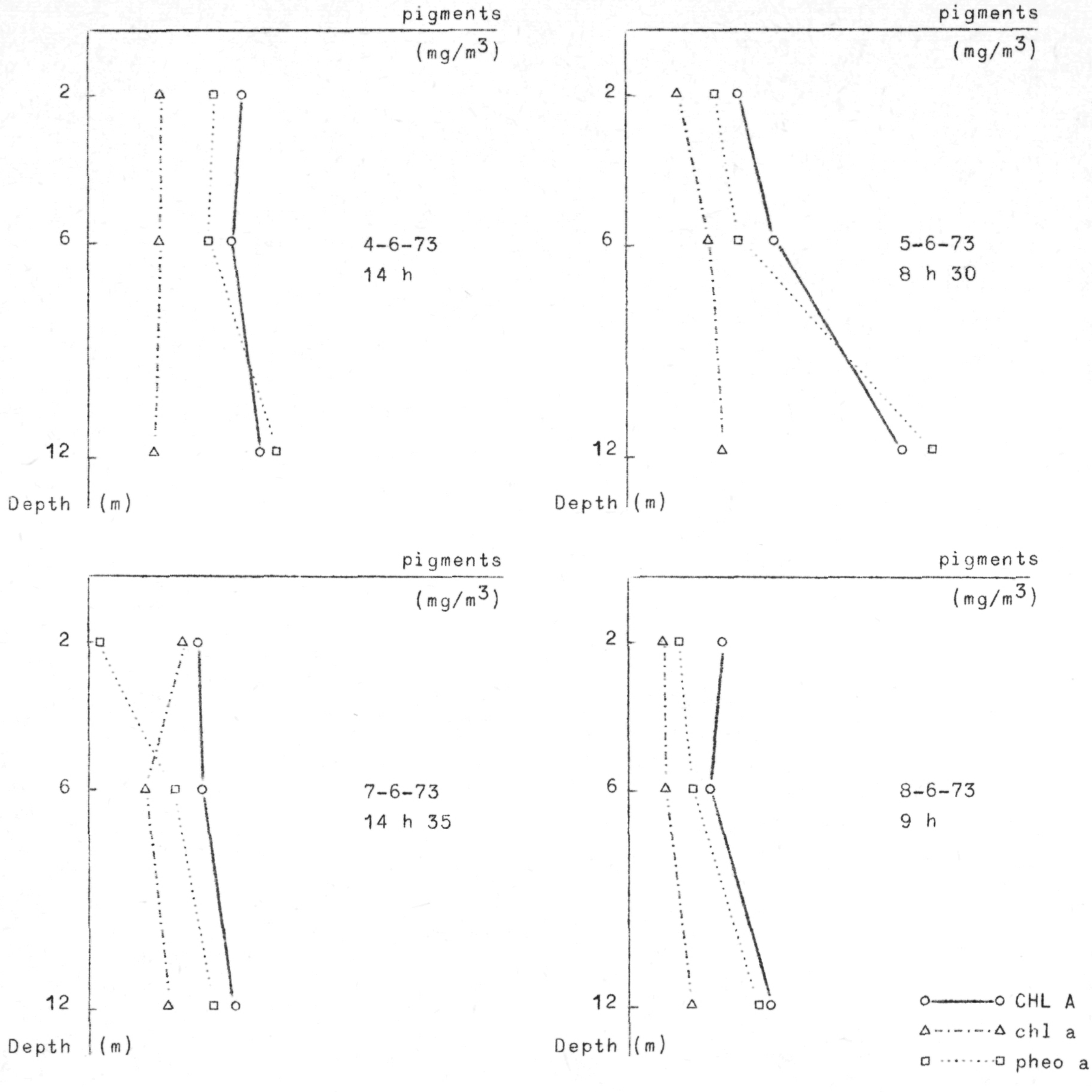


fig. 7.12.- Station M06 - Vertical profiles.

sharp variations of the phytoplankton biomass should be explained by the moving of the water mass rather than by the own physiology of the species. Both explanations are however acceptable.

Therefore, since within one week, significant variations of the phytoplankton biomass are not observable, a rapid spatial survey of the area delimited by the mathematical model will give a better picture of the biomass in the investigated area.

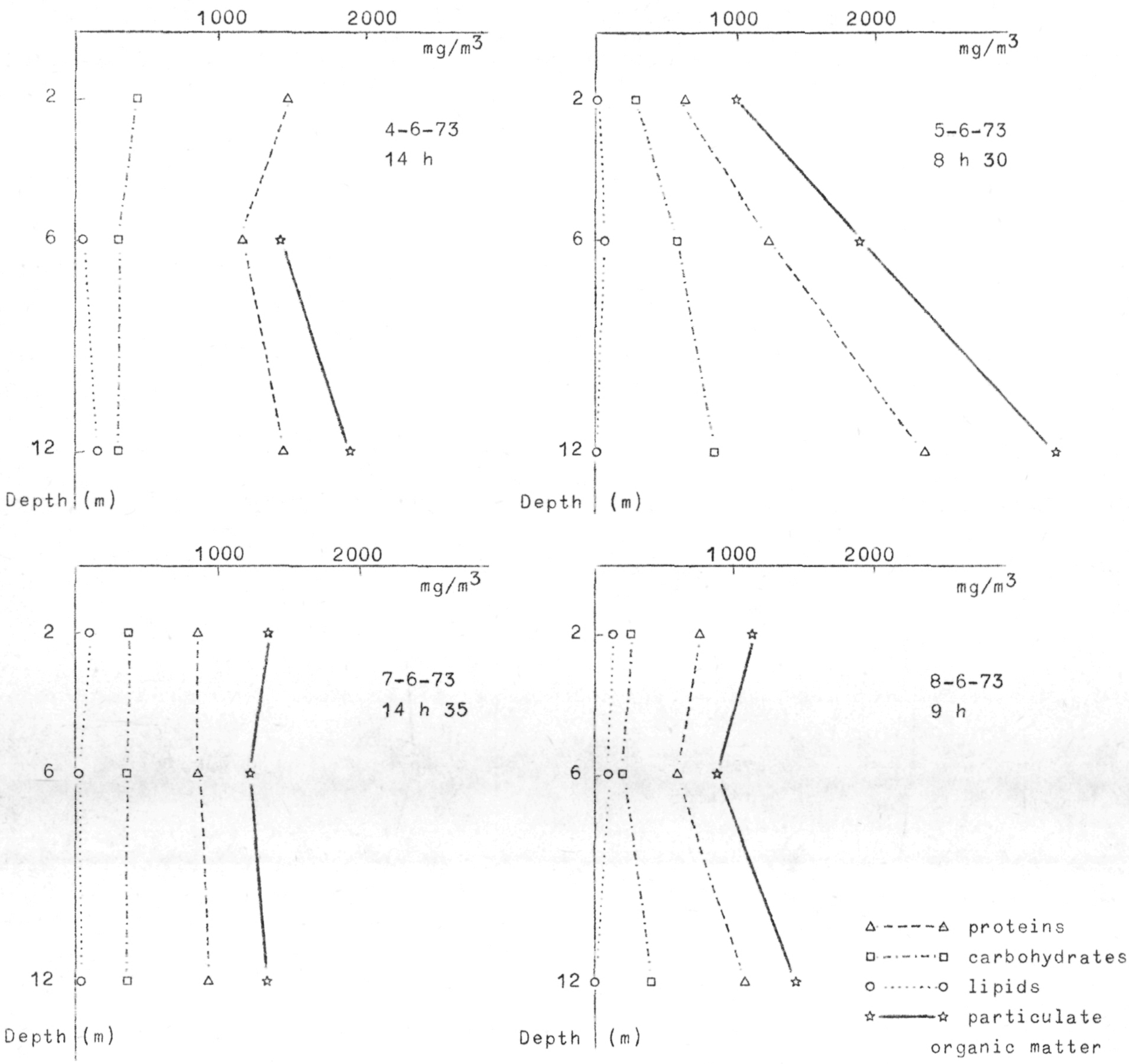


fig. 7.13.- Station M06 - Vertical profiles.

In addition, the purpose of the method of the fixed stations could be extended by intensive record of data connected with simultaneous sampling in some near points.

2.- Approach to the seasonal variation within the area delimited by the mathematical model

This study includes four parts treating of distribution of chlorophyll a, particulate organic matter and phytoplankton cells. The fourth part concerns the relative importance of detritus in the whole system.

Results will discuss about five cruises for chlorophyll and particulate organic matter and seven cruises for phytoplankton cells. The rapid changes of biomass and phytoplankton do not allow, on basis of such limited number of cruises to draw definite conclusions or to estimate the variation rate.

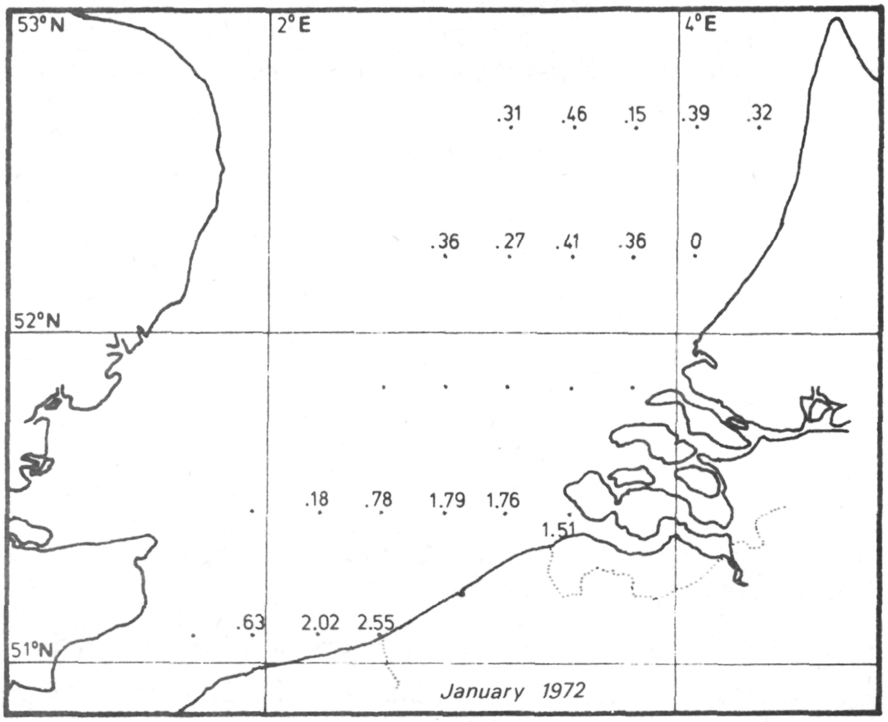
2.1.- Distribution of chlorophyll a

The complete data concerning chlorophyll a concentrations (SCOR, Lorenzen) were detailed in a precedent Technical Report (1972-1973). The present discussion will refer to the distribution of active chlorophyll a [Lorenzen (1967)], the considerable abundance of pheo-pigments a in the area (fig. 7.14) being a cause of error in the estimation of living biomass.

Results (expressed in mg/m^3) plotted on figure 7.15 show a marked decrease when the distance offshore increases. The highest concentrations are observed in Autumn and more especially in Spring.

January excepted (where the biomass seems shifted southwards) these higher concentrations are always located in the estuarine area (Stations M05, M06, M11) with a dilution parallel to the shore towards a direction in prolongation of the estuary. The decrease is particularly sharp near the stations M12 and M07.

This distribution of chlorophyll a allows a division of the area studied into areas of isoconcentrations, more complicated as the sampling period corresponds to a bloom period. This leads to the recognition in January of two zones, in July three zones, in September-October five zones (Autumn bloom) and in April six zones (Spring bloom).



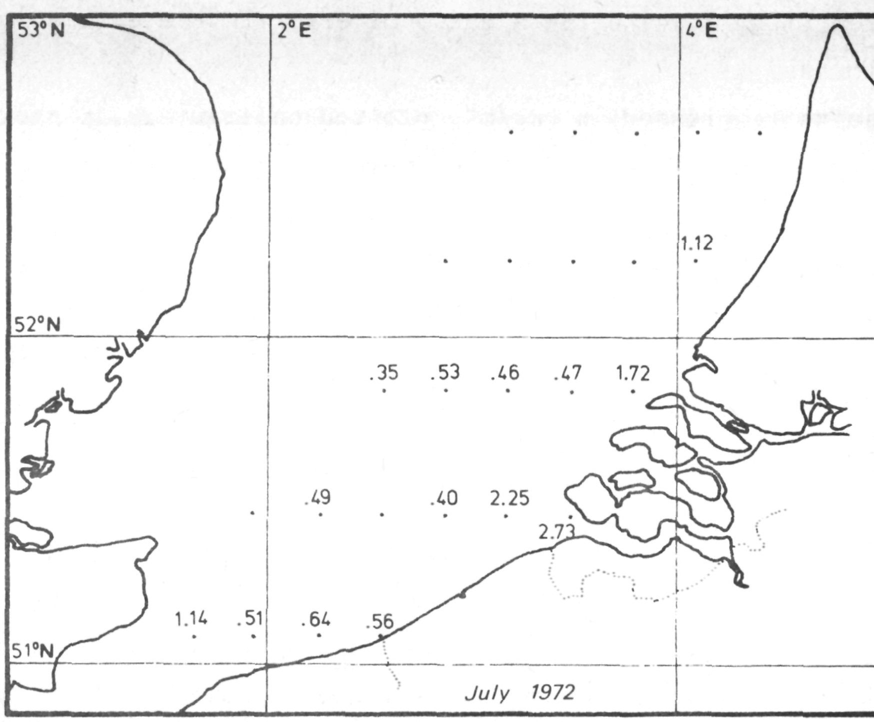
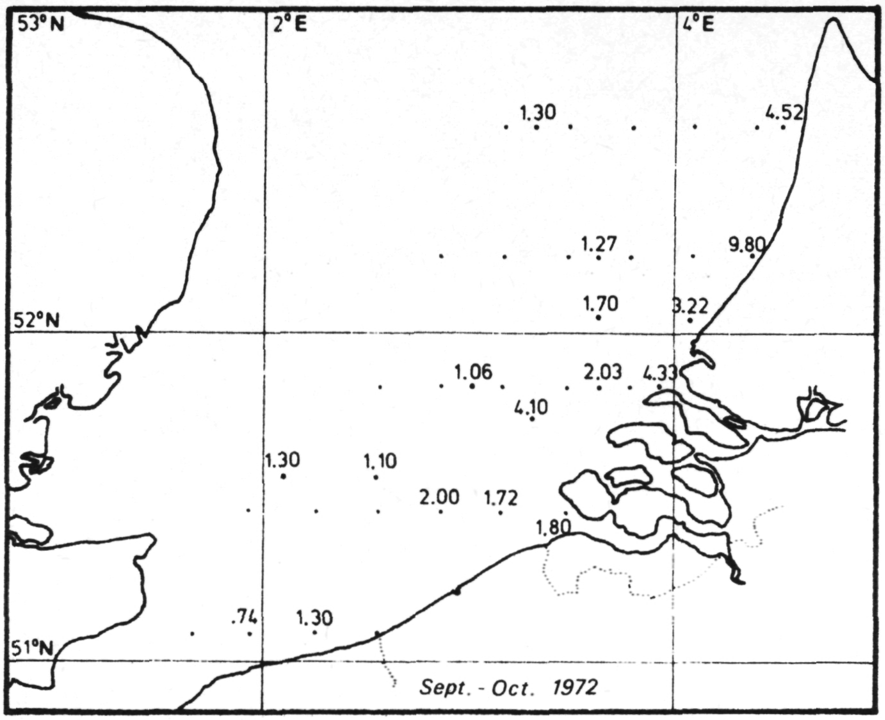


fig. 7.14.- Distribution of pheo-pigments a (mg/m^3).



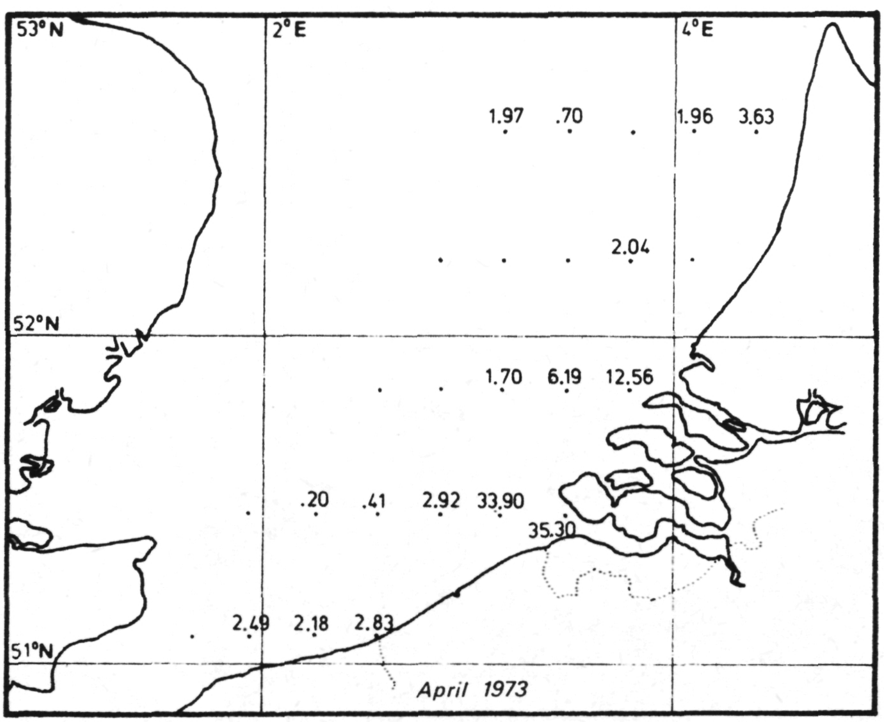


fig. 7.14.- Distribution of pheo-pigments a (mg/m^3).

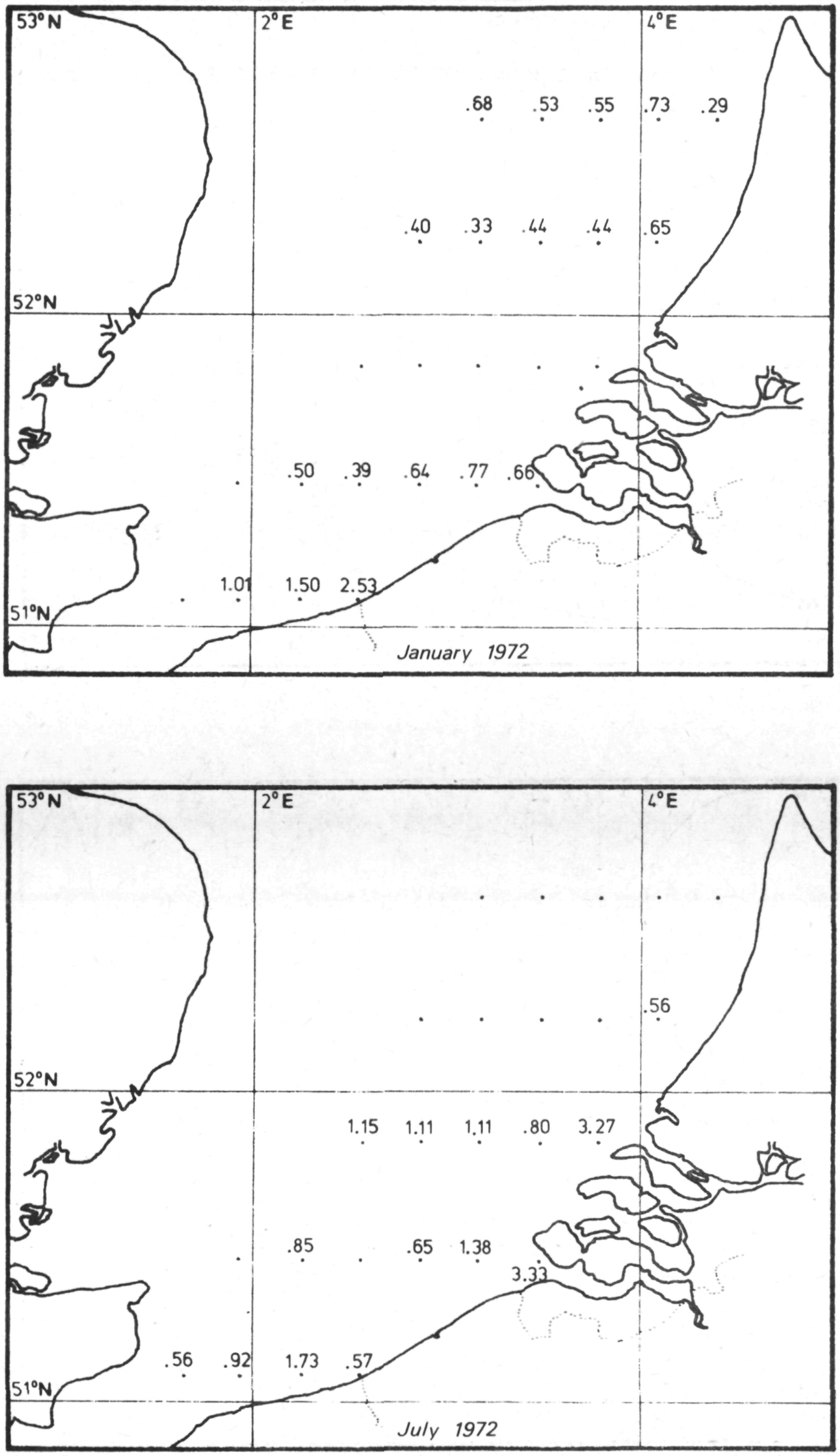
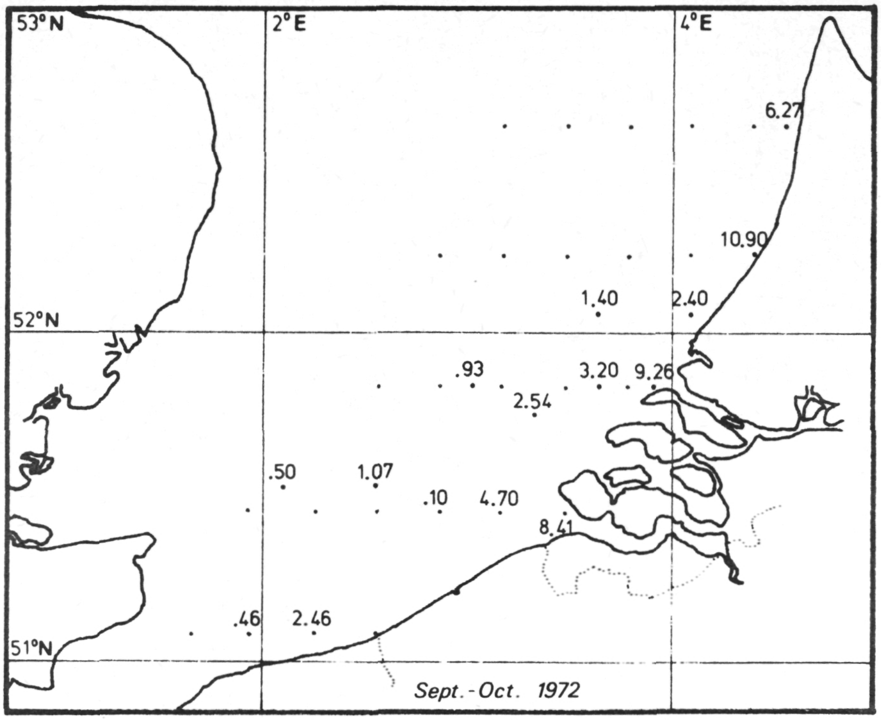


fig. 7.15.- Distribution of chlorophyll a (mg/m^3).



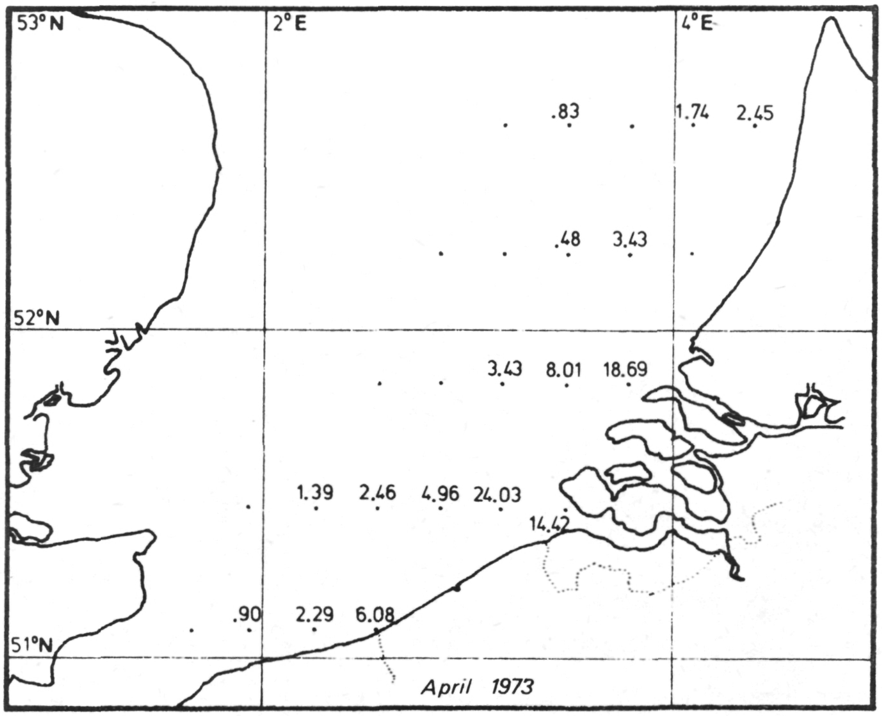
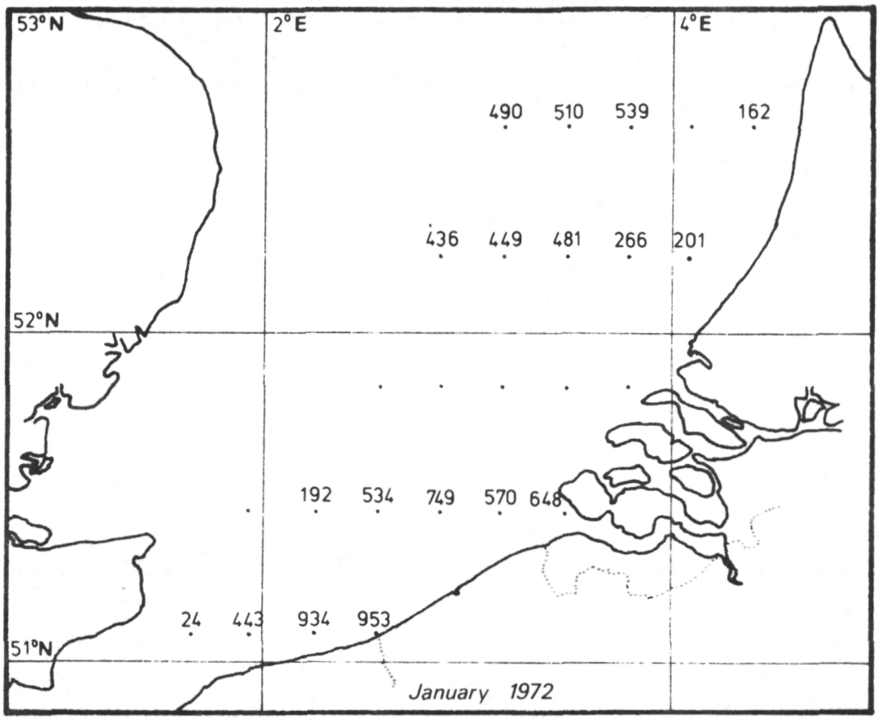


fig. 7.15.- Distribution of chlorophyll a (mg/m^3).



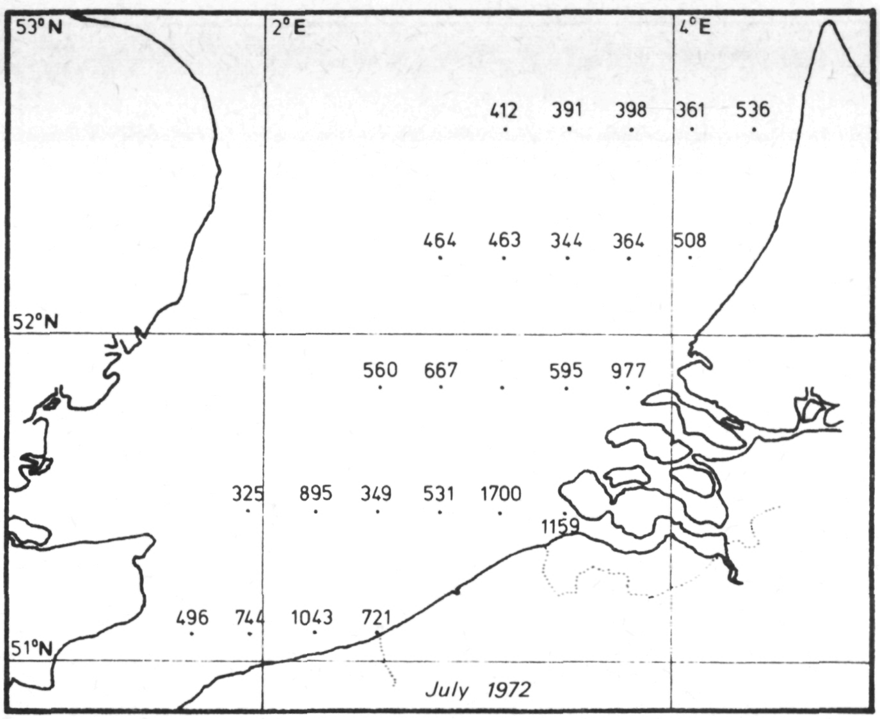


fig. 7.16.- Distribution of particulate organic matter.

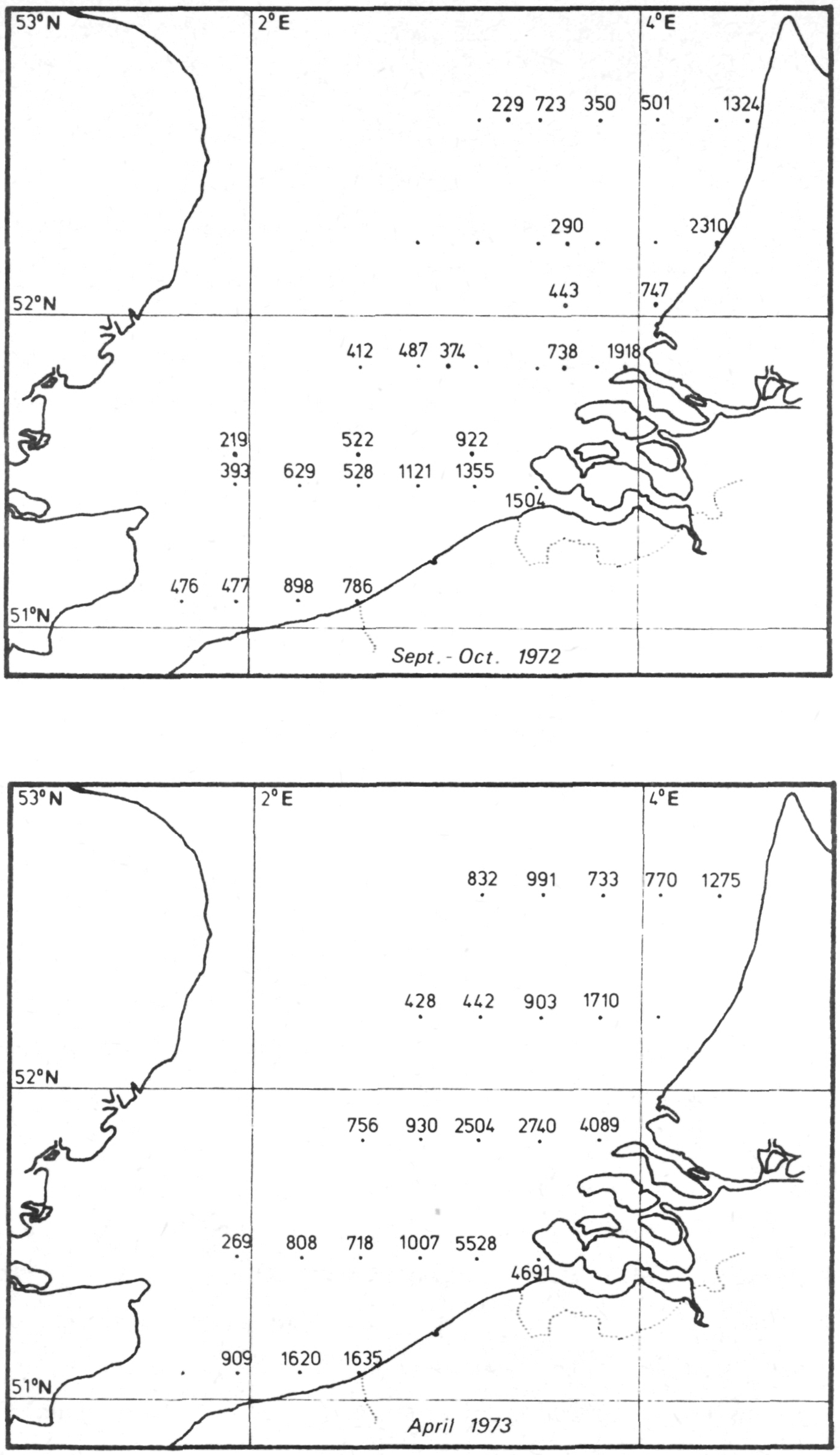


fig. 7.16.- Distribution of particulate organic matter.

2.2.- Distribution of particulate organic matter

Results (expressed in mg/m^3) are plotted on figure 7.16 and are generally in good agreement with chlorophyll a : higher particulate organic concentrations are in accordance with higher chlorophyll a. The lack of concordance corresponds always to an excess of particulate organic matter generally related to a detritus quantity greater than 50 % (see below).

In addition, particulate organic matter data being more complete, they enlight some additional particularities in relation with season : in January, the higher concentrations are not along the coast in the North of the model area; in July the reverse situation exists but with higher concentrations at stations M25, M20, M19; and in September, October, April, the areas subdivision is identical, station M22 excepted.

From these statements it may be concluded that the North part of the area characterizes always an important zone of weak concentrations.

2.3.- Distribution of phytoplankton

2.3.1.-Quantitative aspect

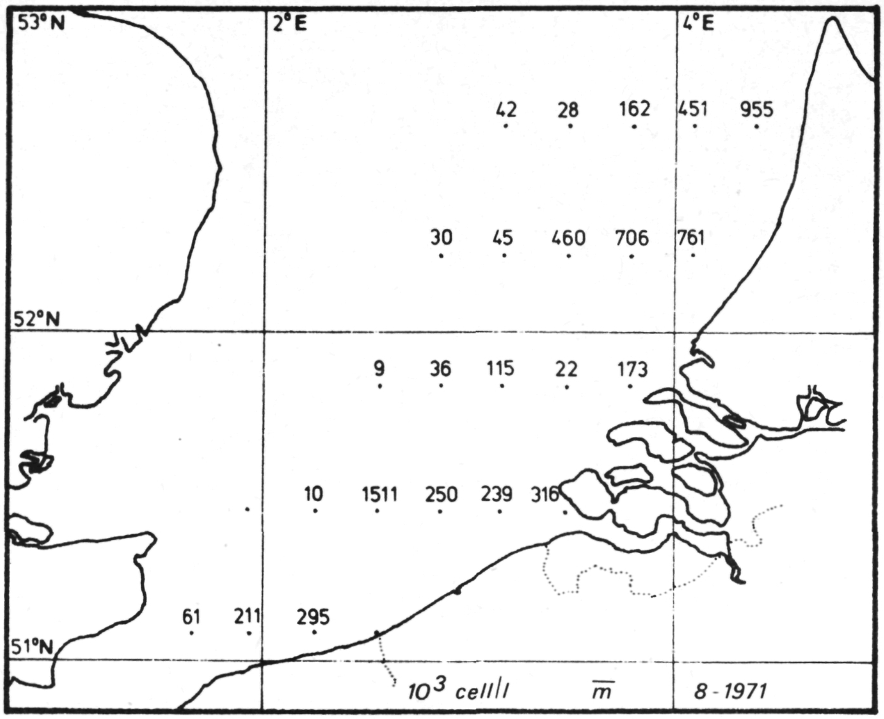
a) Total abundance

This includes living cells (flagellates excepted) and death cells calculated as the pondered average at each sampled station. Results are plotted on figures 7.17 and 7.18 and show the following characteristics :

- the maximum of the phytoplankton biomass occurs in Spring and Autumn along the shore;
- minima are observed in Winter;
- occurences of maximum quantities in Summer are at offshore stations.

These results are in good agreement with the classical picture of the phytoplankton distribution in coastal waters; nevertheless some particularities proper to the area are to be pointed out :

- in addition to seasonal fluctuations there are also annual variations due to the simultaneousness of the seasonal cycles (example cruises of 09/71 and 09/72) (figs. 7.17, 7.18);



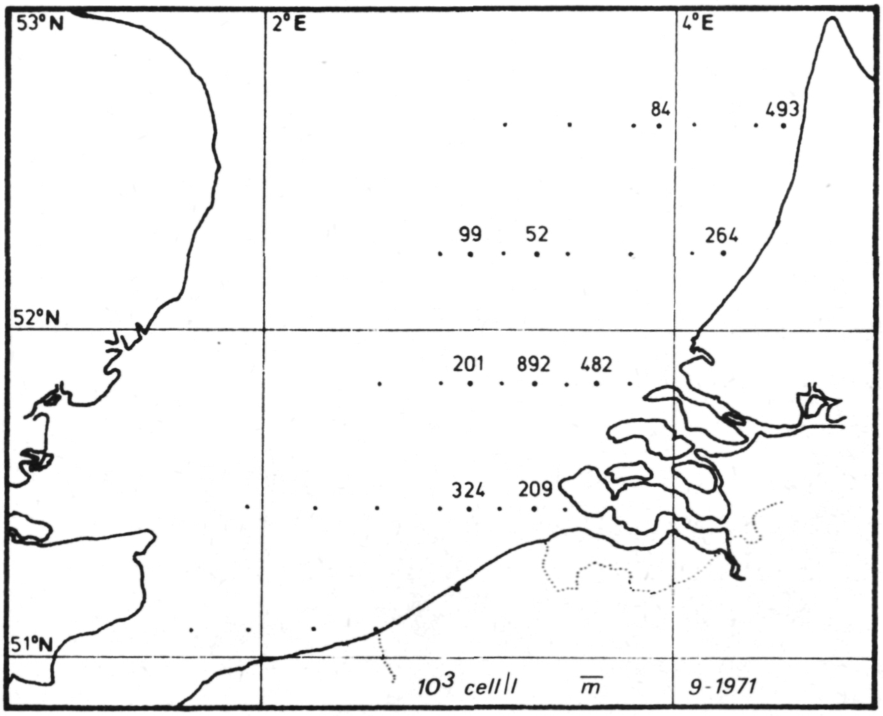
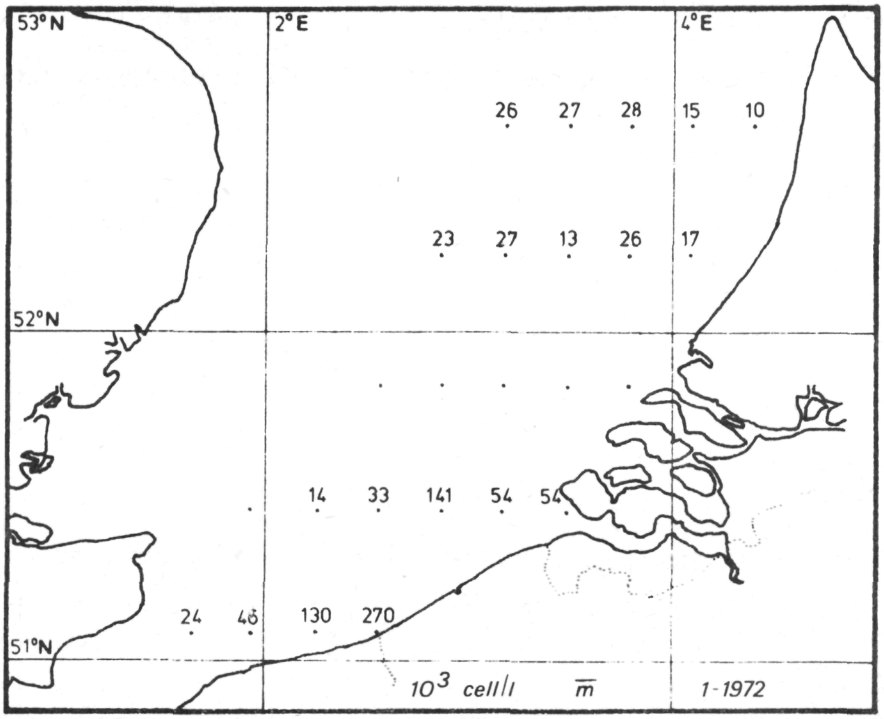


fig. 7.17.- Distribution of phytoplankton : total abundance.



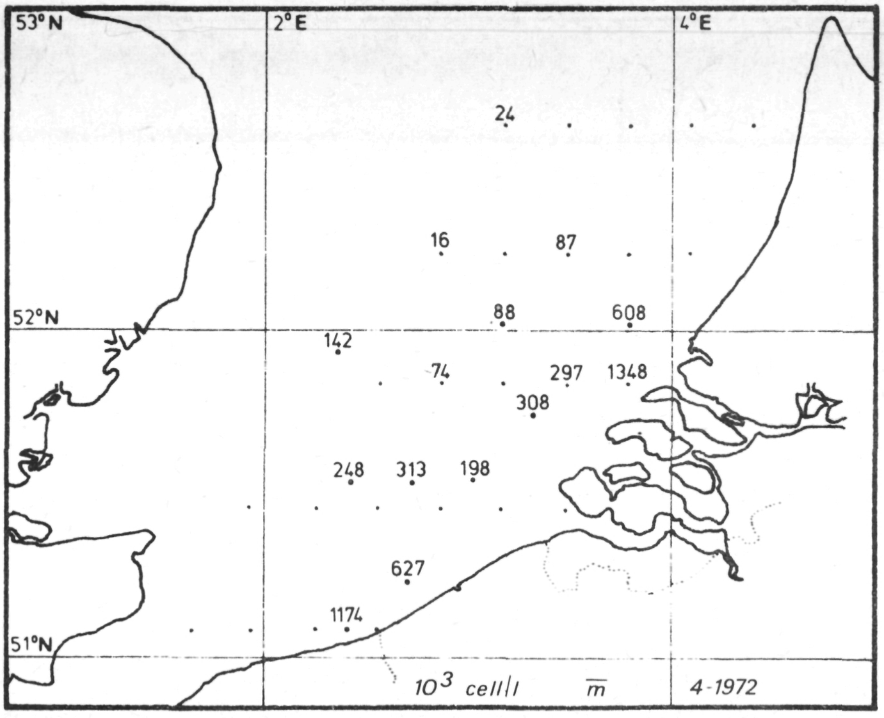


fig. 7.17.- Distribution of phytoplankton : total abundance.

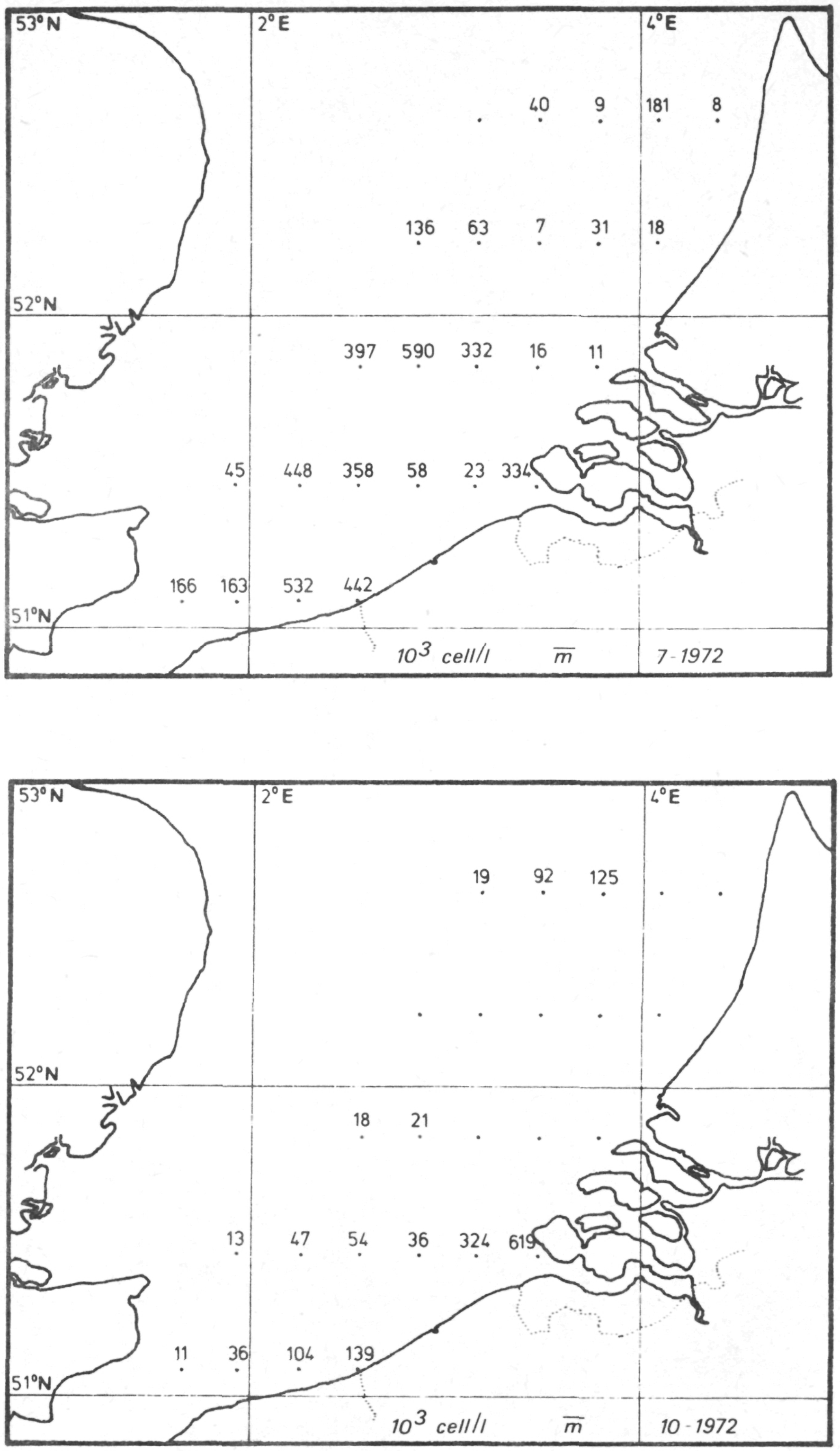


fig. 7.17.- Distribution of phytoplankton : total abundance.

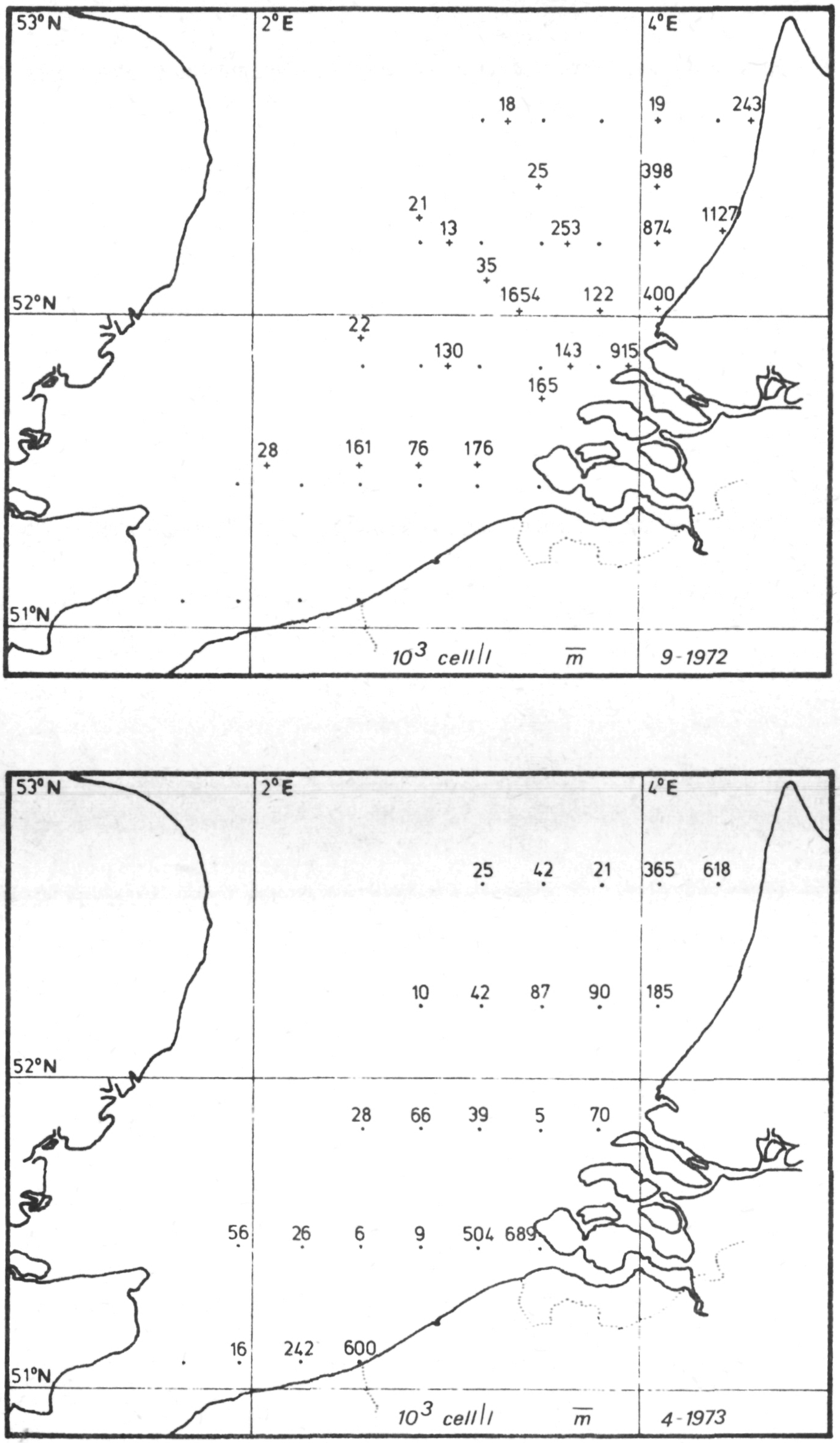


fig. 7.18.- Distribution of phytoplankton : total abundance.

- in spite of seasonal differences, the highest quantities are located in Autumn as well as in Spring, in two coastal centers, one in the northern part and the other in the southern part of the area;

- in any season, the southern zone of the area owns a higher density in cells than the northern zone with a minimum in the North-West;

- for any cruise there is a particular zone of lower concentrations located variably at stations M06, M07 or M12. These stations compared to those of immediate vicinity correspond probably to special conditions in relation with the extent of the estuarine influence.

b) Importance of flagellates

The counting of flagellates in coastal waters presents many difficulties and was therefore not regularly reported.

Results plotted on figures 7.19 and 7.20 show that the highest summer quantity occurs in the offshore area with nevertheless a higher flagellates percentage near the coast.

On the other hand, the Autumn maximum quantity is higher than that found in Summer and occurs along the coast and in front of the estuary, but does not correspond to a maximum percentage.

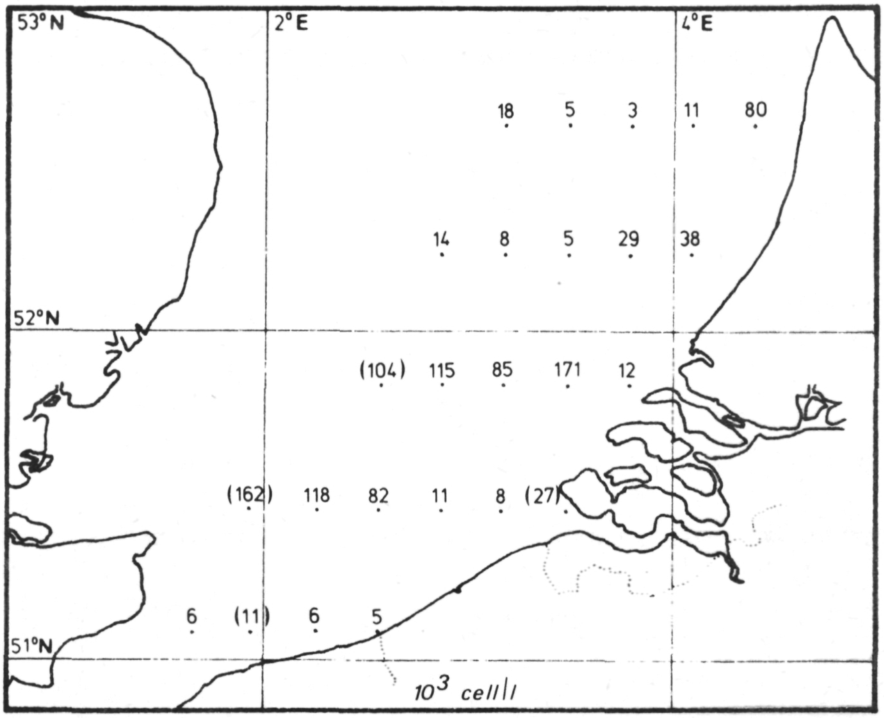
On the basis of too little simultaneous results, no correlation could be calculated between chlorophyll a and total cell number (flagellates included). Nevertheless the large quantity of chlorophyll and the high productivity recorded in the coastal areas and in front of the estuary point out the considerable importance of flagellates.

2.3.2.- Qualitative aspect

a) Species

More than 90 % of the total cell quantity (flagellates excepted) is made up by diatoms. The distribution of the most important species has been studied and reported in synthesis report (1973).

The data allow only a rough outline of the seasonal succession. A particular point must however be mentioned about the distribution of *Rhizosolenia Shrubsolei* : abundant where the total number of cells is reduced, this species is located principally in front of the estuary.



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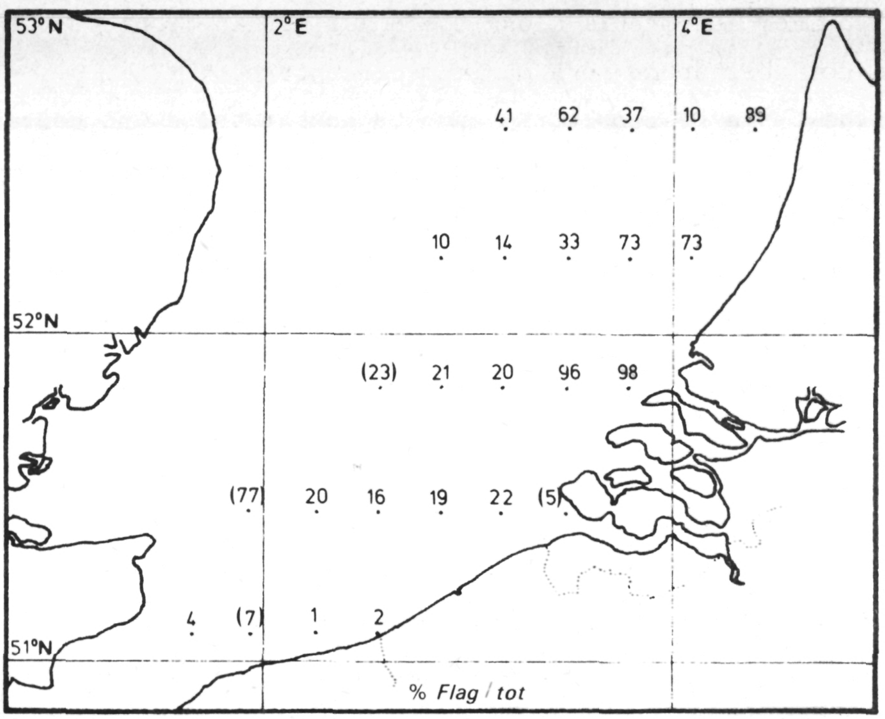
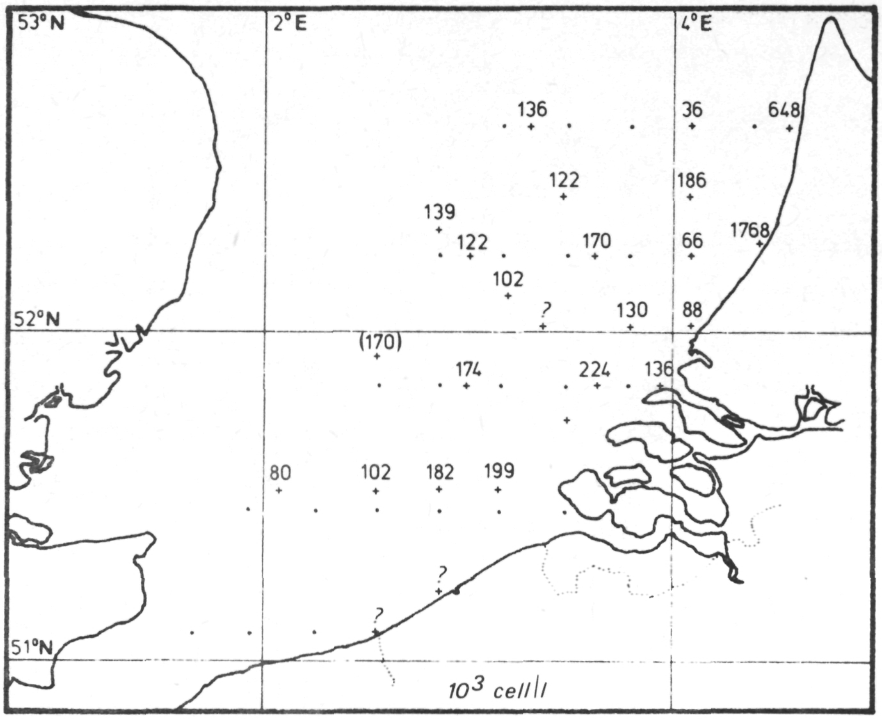


fig. 7.19.- Distribution of flagellates : 0 m ( ) , 5 m .



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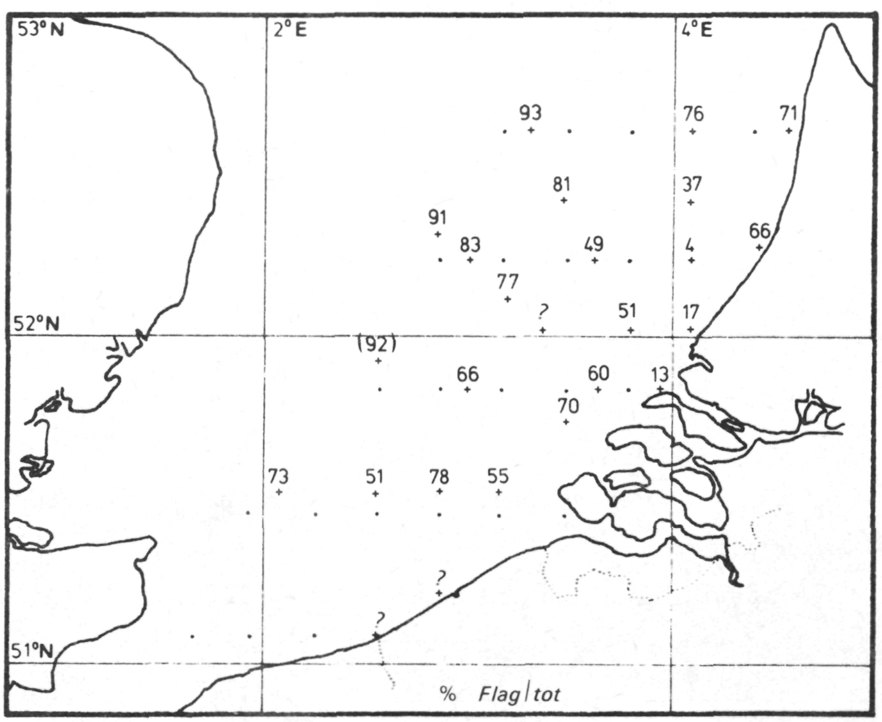


fig. 7.20.- Distribution of flagellates : 0 m ( ) , 5 m .

Because of its particular behaviour, it could possibly be tested as an indicator species (in correlation with other factors).

b) Diversity index

The diversity index (Shanon) supplies information about the phytoplankton population as an entity and particularly indicates its degree of heterogeneity. As it is linked with the evolution of an ecosystem it indicates also the type of population which is concerned : a low index coupled with a high biomass is often associated to a high productivity; a high index with a lower quantity characterizes a succession; on the contrary, a high index linked with a large cell quantity indicates a mixing area and lastly a low index and a weak biomass do correspond sometimes to a selective influence.

In the present case, the diversity index has been computed on all phytoplankton cells, flagellates excepted. The results are plotted on figure 7.21 : the lowest values of the diversity index are found in Summer (07,08/1971 and 06/1972) explained by local blooms of the species *Rhizosolenia Stolterfoltii*. On the other hand, the concept of Spring bloom is confirmed at Stations M21, M22 (04/1973) where the index reaches values as low as 0.5 and 0.8 .

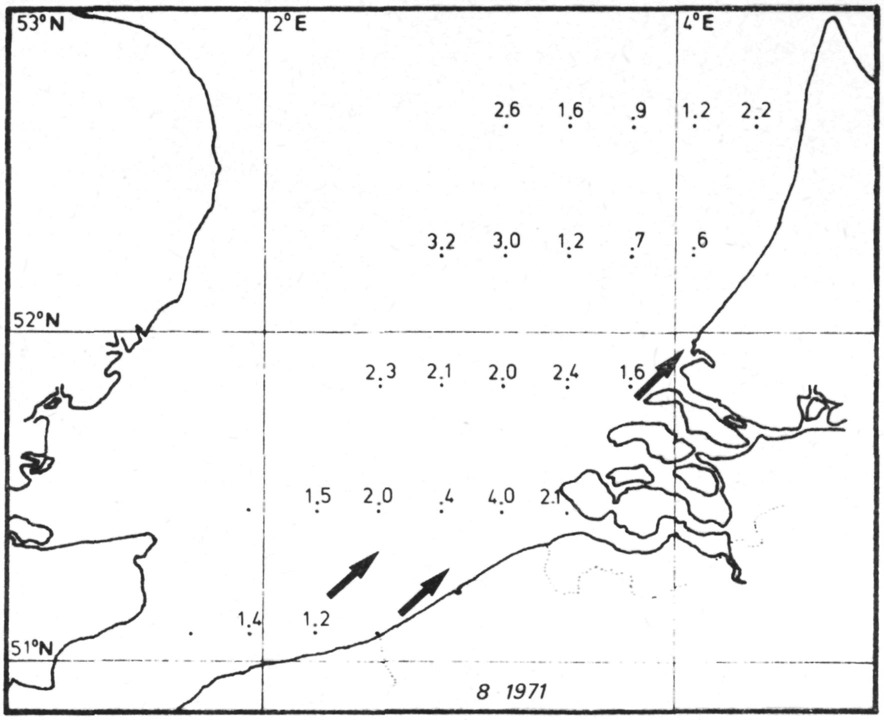
Large cell density associated with a low index corresponding with a high productivity are found, for instance, at Stations M01, M05, M21, M22 (04/1973) and M02, M03, M11 (07/1971).

Nearshore and in a more extended area in front of the estuaries, a high index of diversity is linked to a high biomass. It is the case for M01/01/1972, M07/01/1972, M01/10/1972, M02/M06/04/1973, M05/06/1972.

These stations support a mixed population and the area as such delimited could therefore be considered as corresponding to the estuary influence on phytoplankton populations.

At other stations, often situated at the limit of the above mentioned area (M16 ...) a particular weak biomass is linked to a high index of diversity. It could indicate in these particular points the end of a certain population type.

In fact, the variations between diversity index and cell number are more considerable in the estuarine zone and its limit. Effectively



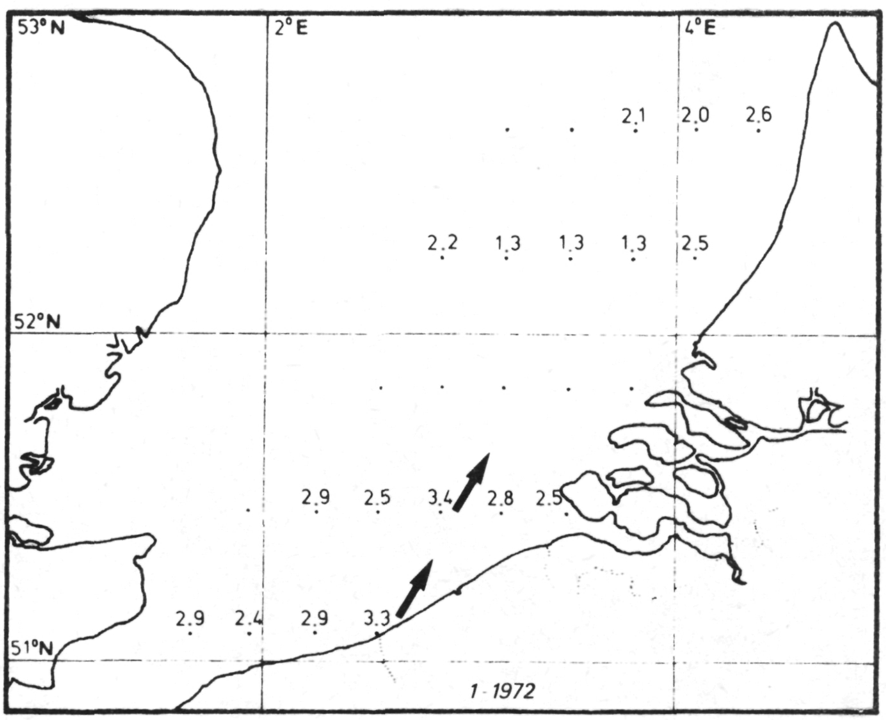


fig. 7.21.- Diversity index.

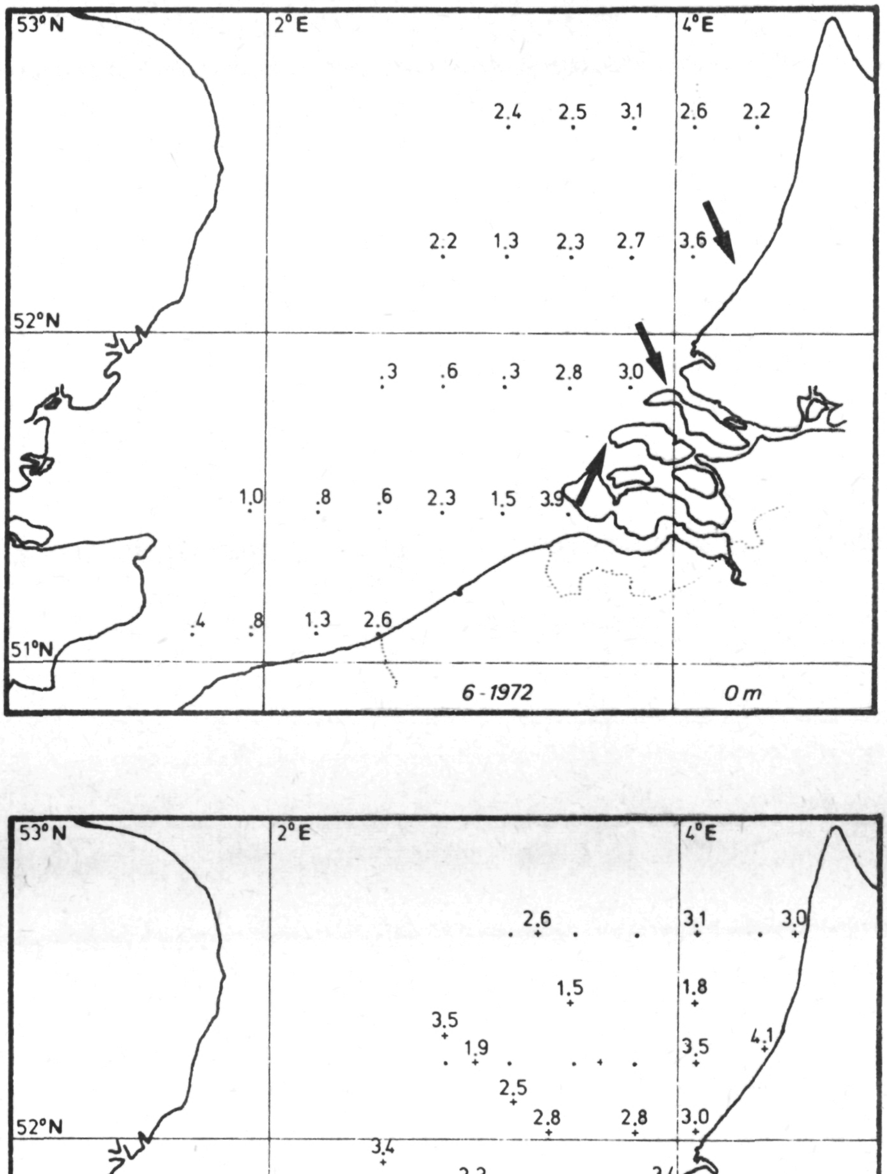


fig. 7.21.- Diversity index.

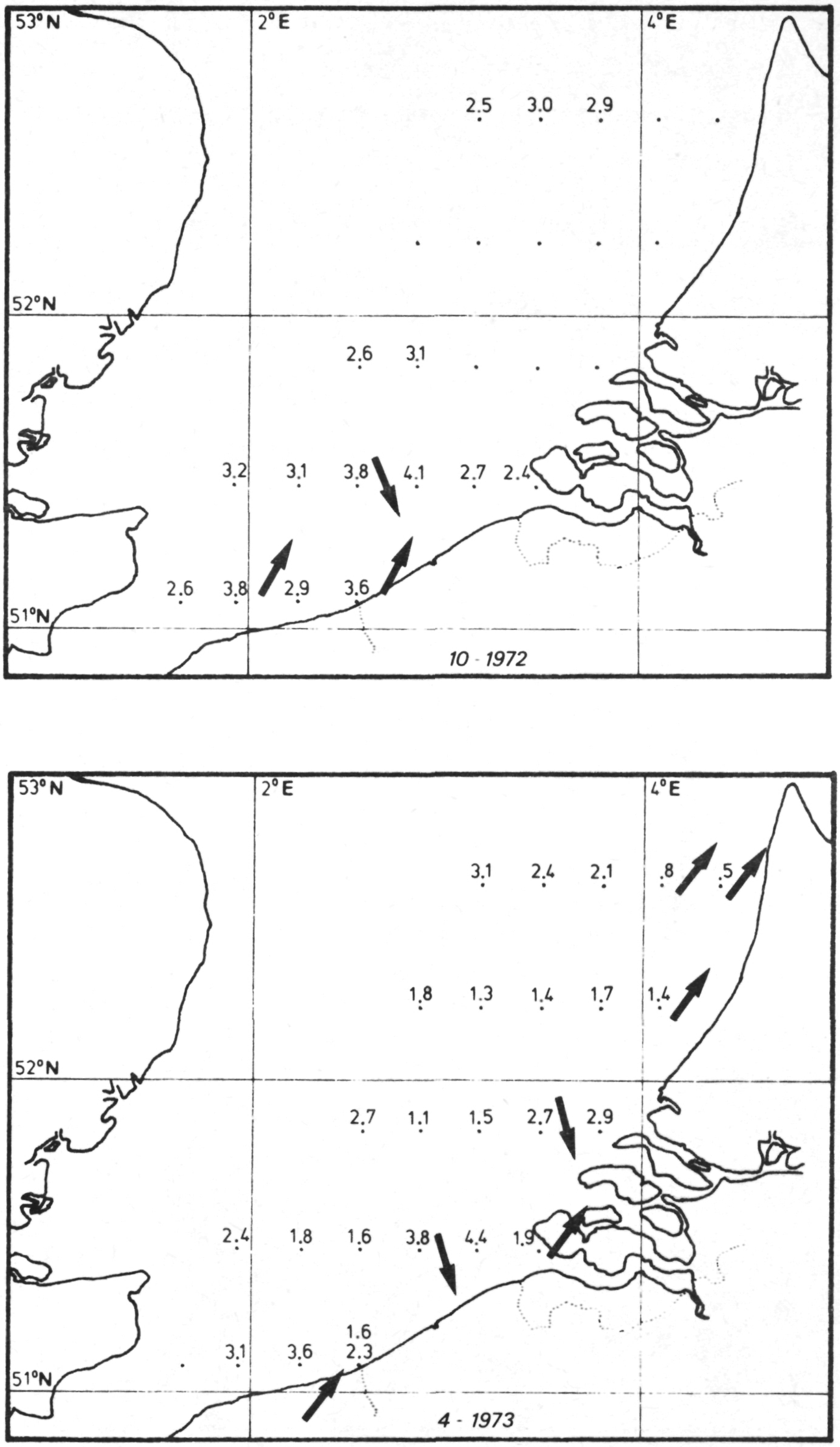


fig. 7.21.- Diversity index.

identical stations do belong at one time to the mixing area, at others to the productive area or the limit between the two. This is probably to be connected with the moving of the waters with tide and the variation of the estuarine influence with the season.

3.- Relative importance of dead cells and detritus in the area

In this study, the estimate of relative proportion of living phytoplankton and detritus is given by two parameters : one concerns the cell countings and is expressed by the ratio dead cells/total cells (unfortunately the counting of dead cells was not accomplished for each cruise and results plotted on figure 7.22 do not allow real conclusion); the other one gives an estimate of the quantity of detrital material evaluated by the regression particulate organic matters/pigments (Synthesis

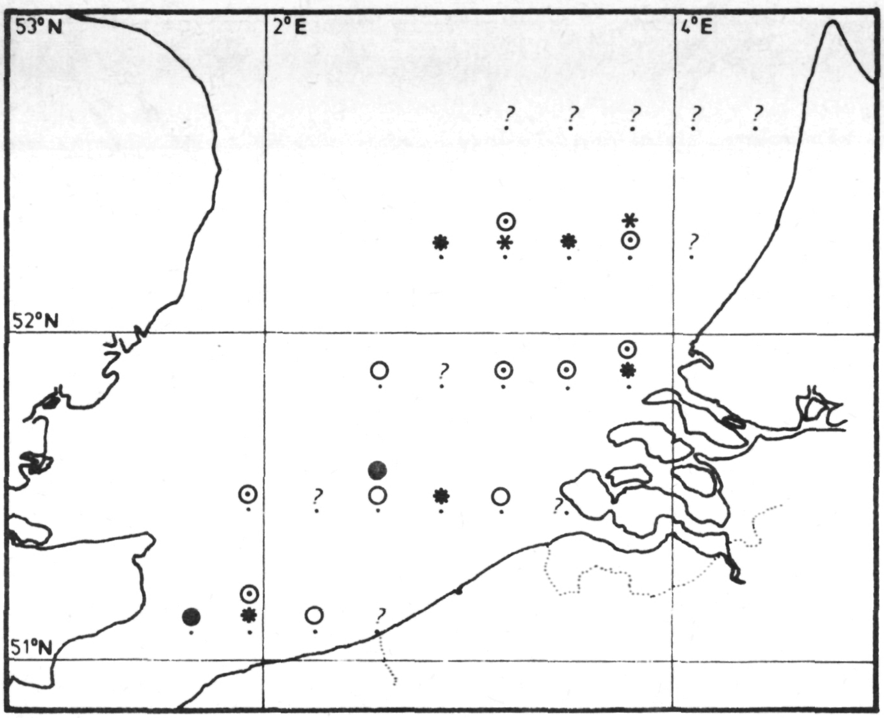


fig. 7.22.- % dead cells/total cells.

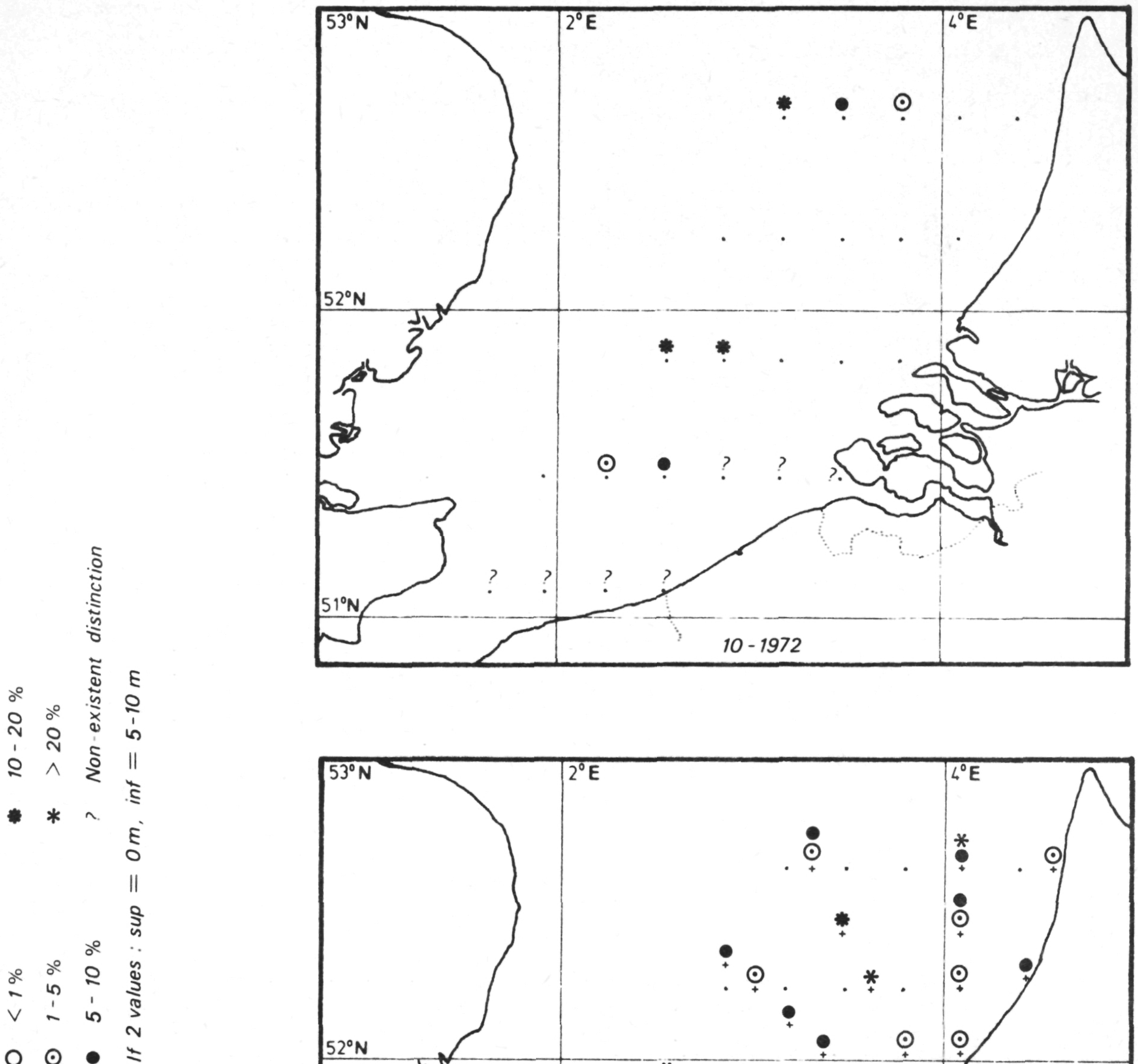


fig. 7.22.- % dead cells/total cells.

Report 1972, Technical Report 1973). This last gives numerous data concerning four surveys allowing a more detailed analysis. Results are plotted on Table 7.1.

Table 7.1

Chlorophylls / Particulate organic matters relationships

	r	P	Slope	Detritus	$\overline{POM}$	% detritus
A) Whole area delimited by the mathematical model						
1) pheo a + chl a						
January 1972	0.85	0.99	158	265	483	55
July 1972	0.70	0.99	159	469	815	57
September 1972	0.98	0.99	112	132	836	16
April 1973	0.95	0.99	79	832	1973	40
2) chl a						
January 1972	0.70	0.99	299	287	483	59
July 1972	0.55	0.95	240	522	815	64
September 1972	0.98	0.99	187	225	838	27
April 1973	0.96	0.99	210	661	1973	34
B) April cruise parted in two areas : inshore P/CH > 1; offshore P/CH < 1						
1) pheo a + chl a						
P/CH > 1	0.99	0.99	78	661	2479	24
P/CH < 1	0.94	0.99	144	552	1174	46
2) chl a						
P/CH > 1	0.95	0.99	202	470	2479	16
P/CH < 1	0.91	0.99	240	615	1174	52

r : correlation coefficient
P : safety of the correlation
$\overline{POM}$: particulate organic matter, average.

3.1.- Comparative study

It shows in front of the estuary a weak value of the ratio dead cells/total cells in good agreement with a weak quantity of detritus (fig. 7.23).

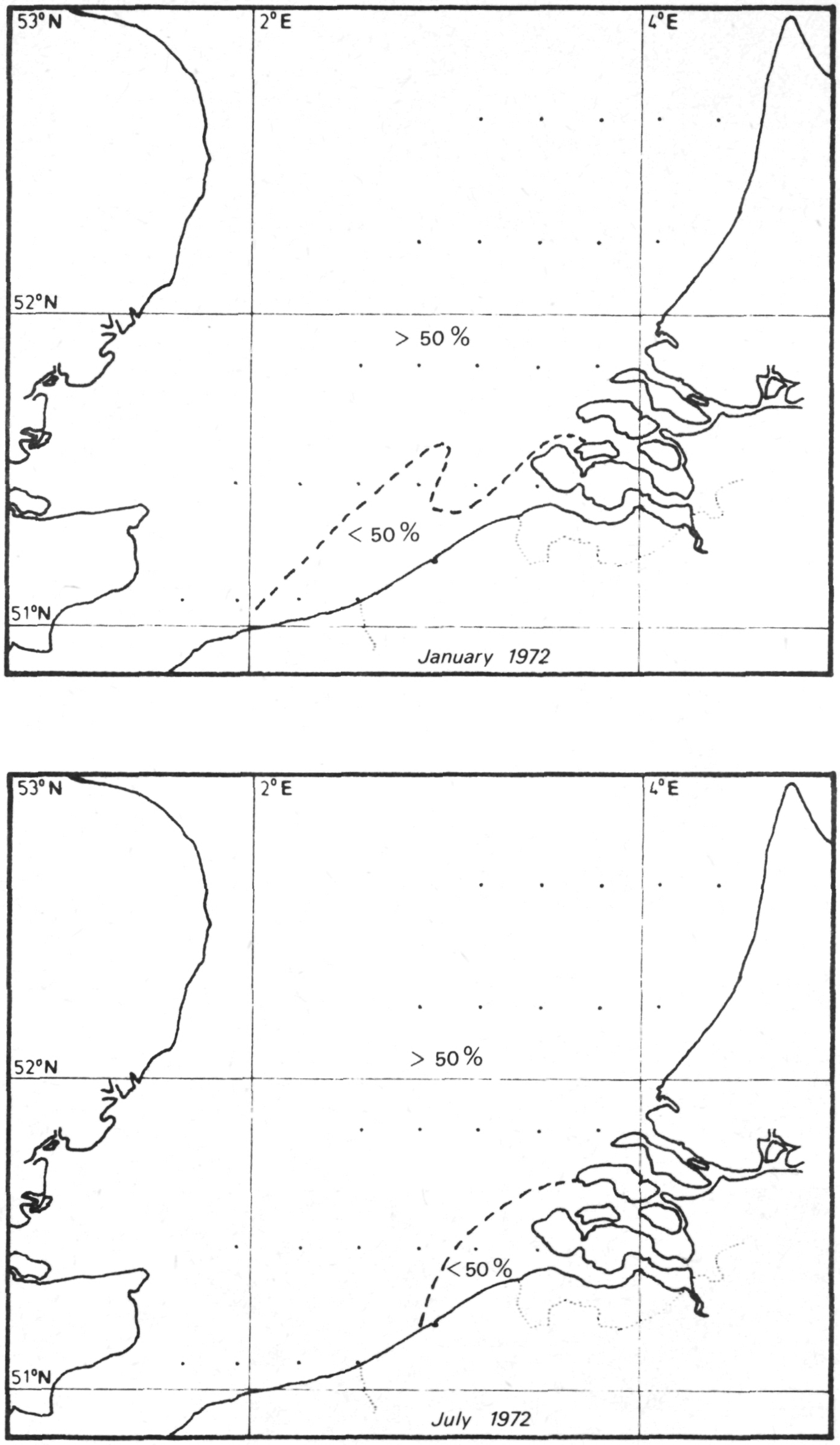
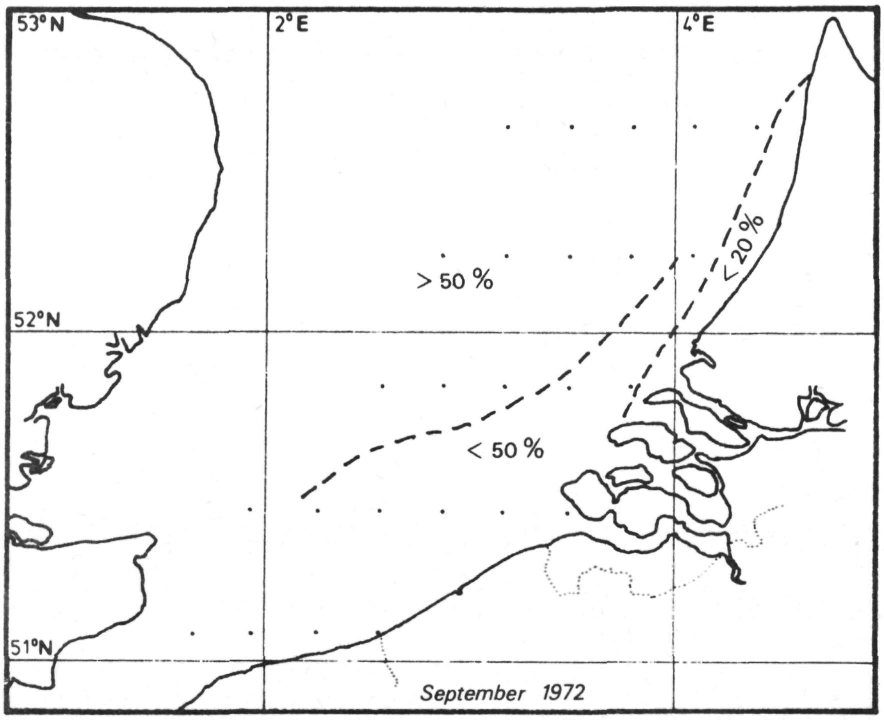


fig. 7.23.- Estimate of detrital particulate organic matter.



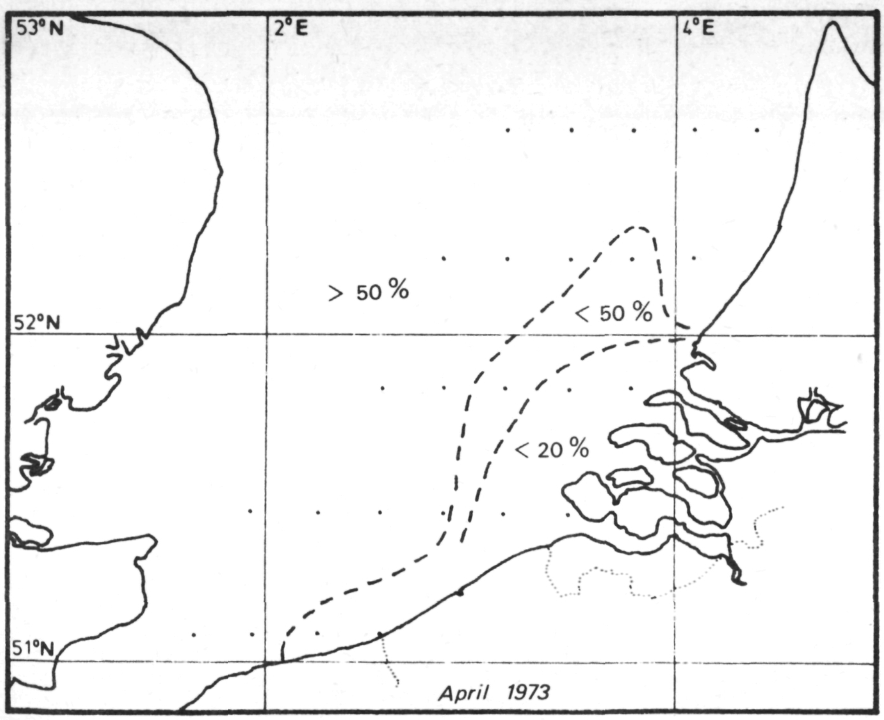


fig. 7.23.- Estimate of detrital particulate organic matter.

(2) $$\dot{X} = F[X(t), \vartheta, Y(t)]$$

with Y the excitating vector.

The vectors X and Y are known by their values in time series $\tilde{X}(t_k)$ and $\tilde{Y}(t_k)$ at some measure times t_k .

In the building of the model, there are two problems to be considered. It is necessary firstly to fix the analytical forms F of the interactions and secondly to determine the value of the vector ϑ so that at the times t_k the calculated values of X by integrating (2) coincide with the observed values $\tilde{X}$.

1.- Determination of the analytical forms of the interactions

A statistical preprocessing of $\tilde{X}$ and $\tilde{Y}$ may clarify the various interactions. The correlation analysis provides information about series having similar behaviours more than firm relations of causality [Pichot-Hecq (1972)]. The spectral analysis shows up the periodicities of the series and the buffer effects between them [King and Mather (1972)].

It is clear that most of the interactions are non linear. The main semi-empirical laws cited in the litterature are the Verhulst relation (1845) for the logistic growths, the Van 't Hof one (1885) for the activation of metabolic processus by the temperature, the Lotka one (1926) for the prey-predator interaction, the Monod one (1942) for every phenomenon having a level of saturation, etc.

Since then, all the models were built by using more or less sophisticated combinations of these semi-empirical relations. One particularly interesting exception is to be pointed out . Mobley (1973) proposes a systematic way of determing F . He considers that the interactions are linear, bilinear and/or quadratic, tests every hypothesis between H_0 (all the coefficients are zero) and H_N (all the coefficients are different from zero) and retains the hypothesis which minimizes a likelihood ratio statistic expressed as a non-central F-variable. His method has the disadvantage to be restricted at most to the quadratic forms and to require an important CPU time.

2.- Determination of the interactions coefficients

If F is supposed to be known, the parameter vector ϑ must be now determined. As these parameters introduce the mean effect of all the variables that one must (or wants to) ignore, they do not have at all a meaning of universal constants. So, it is sometimes hazardous to put in a model of an ecosystem values of coefficients fitted for another ecosystem or still for an aquarium where one variable is studied in function of two or three other ones, everything else remaining constant.

Thus it is absolutely necessary to estimate ϑ from the information provided by $\tilde{X}$ and $\tilde{Y}$. One may choose as the best estimate ϑ^* of the vector ϑ, the one which minimizes the object function $G_1(\vartheta)$, *i.e.* the error between $X(t_k)$ calculated by integrating (2) and $\tilde{X}(t_k)$ observed.

(3) $$G_1(\vartheta^*) = \min_{\vartheta} G_1(\vartheta) = \min_{\vartheta} \sum_i \sum_k [X_i(t_k,\vartheta) - \tilde{X}_i(t_k)]^2 \ .$$

It is a problem of optimization with constraints. These are the system of differential equations (2) and the initial conditions $X_0 = X(t_0)$. This problem may be tackled in two different ways :

2.1.- The gradient method

One may chose the ϑ^* which realizes the minimum of the error of the derivatives. In this case, the object function to be minimized is

(4) $$G_2(\vartheta^*) = \min_{\vartheta} G_2(\vartheta) = \min_{\vartheta} \sum_i \sum_k \{\dot{\tilde{X}}_i(t_k) - F_i[X(t_k),\vartheta,Y(t_k)]\}^2 \ .$$

It requires the evaluation of the derivatives by spline functions, the minimization of G_2 and the integration of the differential system for which the procedures are explicited in appendix.

One may modify the object function $G_2(\vartheta)$ to take the possible disparities of the accuracy of the measures into account by balancing every term of the sum with a factor $w_{i,k}$ inversely proportional to the variance of the measure error of $\tilde{X}_i(t_k)$. Moreover, when some variables represent phenomena with very quick variations and other ones with very slow variations, one may also balance the partial sums of $G_2(\vartheta)$ in order to normalize the contribution of every variable to the value of G_2.

3.2.- What about detrital particulate organic matter and chlorophyll a in the whole system ?

Four surveys are not sufficient to give a real cycle on the particulate organic matter but allow certain comments in good agreement with the results of Steele and Baird for a similar study in the North Sea in 1961-1962 (1965).

3.2.1.- Particulate organic matter and pheo-pigments

Table 7.1 shows that for any correlation ($\frac{\text{chl a + pheo a}}{\text{POM}}$ or $\frac{\text{chl a}}{\text{POM}}$) the organic residues are similar hence the assumption that the quantity of particulate organic matter connected with pheo-pigments is not very important.

3.2.2.- Particulate organic matter and chlorophyll a

The ratio $\frac{\text{POM}}{\text{chl a}}$ given by the slope of the regression line characterizes the physiologic state of phytoplankton cells : it reaches a maximum value during months of low productivity (January and July 1972) and a minimum value during months of outburst (September 1972, April 1973). This is in good agreement with the data of the literature [Steele-Baird (1965)].

3.2.3.- Detrital particulate organic matter

a) Seasonal variations in the whole system

Detrital particulate organic matter corresponds to the value of particulate organic matter when the chlorophyll becomes off. The detritic quantity varies according to the season : it is higher in April, but the computation of relative proportions (in % on the tables) shows that during the periods of Spring and Autumn detritus form only 30 % of the total particulate organic matter present for a maximum of 64 % during Summer and Winter.

These results point out the importance of detritus in the energy flux.

b) In each station of the system

The estimate of the average detritic quantity peculiar to each cruise was used to evaluate roughly the relative proportions of detritus at each station. Results plotted on figure 7.23 show that the poorest areas in detritus coincide with the richest ones in phytoplankton.

In order to confirm this assumption, we have used results of April 1973 (owing to a larger number of data) : the system has been parted in two areas corresponding to the two areas delimited previously (Elskens, Synthesis Report 1972) — except for Station M12 — on the basis of the qualitative criterion [Parsons *et al.* (1961)] :

$$\frac{\text{protein}}{\text{carbohydrate}} > 1 \quad , \quad \frac{\text{protein}}{\text{carbohydrate}} < 1 \ .$$

Results show effectively an offshore higher detrital quantity.

c) Qualitative approach — April 1973

Table 7.2

	r	Slope	Detritus	% detritus
Proteins				
P/CH > 1	0.94	128	174	13
P/CH < 1	0.95	118	203	44
Carbohydrates				
P/CH > 1	0.92	74	236	25
P/CH < 1	0.86	122	354	47

Results obtained by the regression of the different metabolites on chlorophyll show not only a different participation of metabolites to detritus but also to the plant cells.

The analysis characterizes a high productivity month and the experiment should be therefore extended to low productivity months in order to draw more general conclusions.

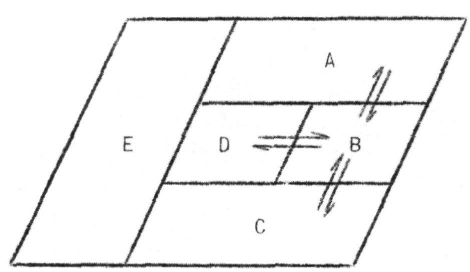
4.- Conclusions

The whole study on phytoplankton biomass (expressed by two parameters chlorophylls, quantity and specificity of cells) and particulate organic matter leads to the conclusion that some fluctuations are specific to the biological system of the investigated area.

- Studies at fixed stations have shown that the daily variations during a period of one week were negligible as compared with seasonal fluctuations; daily cycles, on the opposite, point out some significant variations in concentration, probably explained by the moving of the water mass (Stations M06 and M16 in June and May respectively).

- All parameters investigated confirm the subdivision of the system in two areas (Elskens Synthesis Report 1972) : a high productive coastal zone and one, more offshore, less productive.

The present seasonal study allows even more precision on this concept : the inshore area can be parted in four areas.



ABC : characterizes a high biomass, recorded by the three parameters : chlorophylls, particulate organic matter, cell number.

AC : similar behaviour with prevalence of high values for C .

B : situated in front of the estuary is often poorer in cell number (Diatoms) than A and C .

D : this part is subject to large fluctuations and the limit between D and B is itself variable depending on cruises. The abnormal stations are located in this region.

E : characterizes a low biomass and its character is more oceanic.

- Magnitude and variations of the parameters studied are depending first on the period of the year. The variation rate which is function of time, cannot be approached on the basis of date, as distant in time as those recorded. Indeed, results being too different in range of magnitude do not allow any connection between consecutive cruises.

- Comparative study of living chlorophyll a and particulate organic matter allows the assumption of a control of the carbon motion by the biota and this for any contribution of the detritic organic matter.

Arguments supporting this assumption are :

- the identical position of the areas presenting maximum concentrations of particulate organic matter and chlorophyll a;
- at fixed stations, the synchronism between variations of particulate organic matter and living chlorophyll a and not degraded chlorophyll a (pheo-pigments a);
- the excellent correlation between chlorophyll a and particulate organic matter.

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