Spatial pattern and biochemical content of North Sea zooplankton

(Belgian coast) [1979-1980]

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Abstract

Seasonal changes in chlorophyl and zooplankton concentrations have been studied in comparison with its biochemical content (proteins, lipids and car-bohydrates).

Zooplankton biomass shows a first peak in spring and a second one in au-tumn in the offshore area but only one in spring in the coastal area.

Zooplankton and phytoplankton are distributed into two patches (zooplank-ton offshore and phytoplankton near the coast).

A maximal lipid content suggesting a higher nutritional activity was ob-served in the central area interposed between the two patches.

The lipid content of the zooplankton increases from spring up to autumn and decreases at the end of winter, just before the spring bloom.

Introduction

The traditional schemes of the planktonic food chain usually accept the existence of direct and instantaneous relationships between the phytoplankton and the herbivorous zooplankton (Harvey (1950), Riley (1970), Parsons and Lebrasseur (1970)).

As far as a large scale of time and space is considered, these trophic schemes can be taken as a whole in the Straight of Dover (Hecq (1975)) and in

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the North Sea (CIPS (1977)) where one half of zooplankton is herbivorous and the other one omnivorous.

However many attempts to draw instantaneous correlations between the zooplankton and phytoplankton biomassa have remained unsuccessful (Nihoul *et al.* (1972)). As a matter of fact, the abundance maxima of the different trophic levels (herbivorous, producers, carnivorous) are following one another, in a definite area, with a minimal delay of ten days (Hecq (1976)). As the phytoplankton turnover time is only three days, it seems therefore impossible to explain why zooplankton biomass maximum only appears ten days later if the sole vegetal organic material is immediately used for production.

On the other hand, the rate of the zooplankton oxygen consumption appears to be somewhat higher than the primary production (expressed in the same unit : mg $C/m^2.d$) and thus higher than the grazing rate on the phytoplankton. This suggests that zooplankton can use either non-living (particular or dissolved) organic material, or organic material in the form of metabolic reserves.

This hypothesis has been considered in the present paper through the analysis of the biochemical composition of zooplankton collected during a whole year in the southern part of the North Sea.

Material and methods

Zooplankton samples were collected every month from January 1979 to February 1980 in 20 spots along the belgian coast (fig.2) thanks to the Belgian Navy collaboration and one cubic meter of water was pumped on board and filtered through a 50 μ mesh net ; the samples were immediately deepfrozen and the measurements performed in laboratory within the month. Temperature and salinity were also measured. Chlorophyl content was determined spectrophotometrically (Strickland and Parsons (1968)).

Samples were defreezed and fractionated on the one hand for species numeration and on the other hand for biochemical analysis.

Proteins were extracted in a NaOH 2 N solution during one hour at 100 °C. The extract was then neutralized with HCl 2 N. Protein contents were determined according to Schacterle and Pollack (1973) by using beef serumalbumin as a standard.

Carbohydrates were extracted in a 10 % trichloracetic acid solution during one hour at 100 °C. Carbohydrate amounts were measured according to Dubois et al (1956) by using glucose as a standard.

Fatty acids and lipids were extracted with a 2/1 chloroform-methanol mixture by homogenization with an ultraturrax (Freeman et al. (1957)). The extract was left two hours at 20 °C and overnight at 4 °C. Filtered extracts were purified from non-lipidic substances by the Folch et al. (1956) method. Lipid content was determined according to Marsh and Weinstein (1966) by using stearic acid as a standard.

Chlorophyl content of chloroform extracts of the samples was taken as an estimation of the vegetal biomass.

Dry weight is determined by dessication in an oven during 24 hours at 70 °C.

Dry weight and "organic weight" (OW) are expressed in mg by cubic meter. Organic weight is considered here as the total amount of proteins, carbohydrates and lipids. Chitin and free amino-acids are neglected with the consequence of a 10 % underestimate.

Protein, carbohydrate and lipid contents are expressed in % organic weight.

Results

Most species of the examined zooplankton samples are Copepods : *Temora longicornis*, *Acartia clausi* and *Pseudocalanus elongatus* represent from 90 to 95% of the total. The different species proportions are more or less constant during the whole year and on the whole network.

Total biomass presents variations. Mean evolution of the zooplankton biomass (OW) during the whole year (fig.1 curve 2, dotted line) shows an important peak in June (500 mg/m^3) and another one in October (350 mg/m^3). These peaks follow phytoplankton bloom in April-May (18 mg chl a/m^3) and in October (9 mg chl a/m^3) and correspond to periods of maximal variations of temperature.

Biomass presents an important variability on the whole network : it is due to considerable differences between two groups of homogeneous values : those obtained along the coast and those offshore. Indeed June data show a
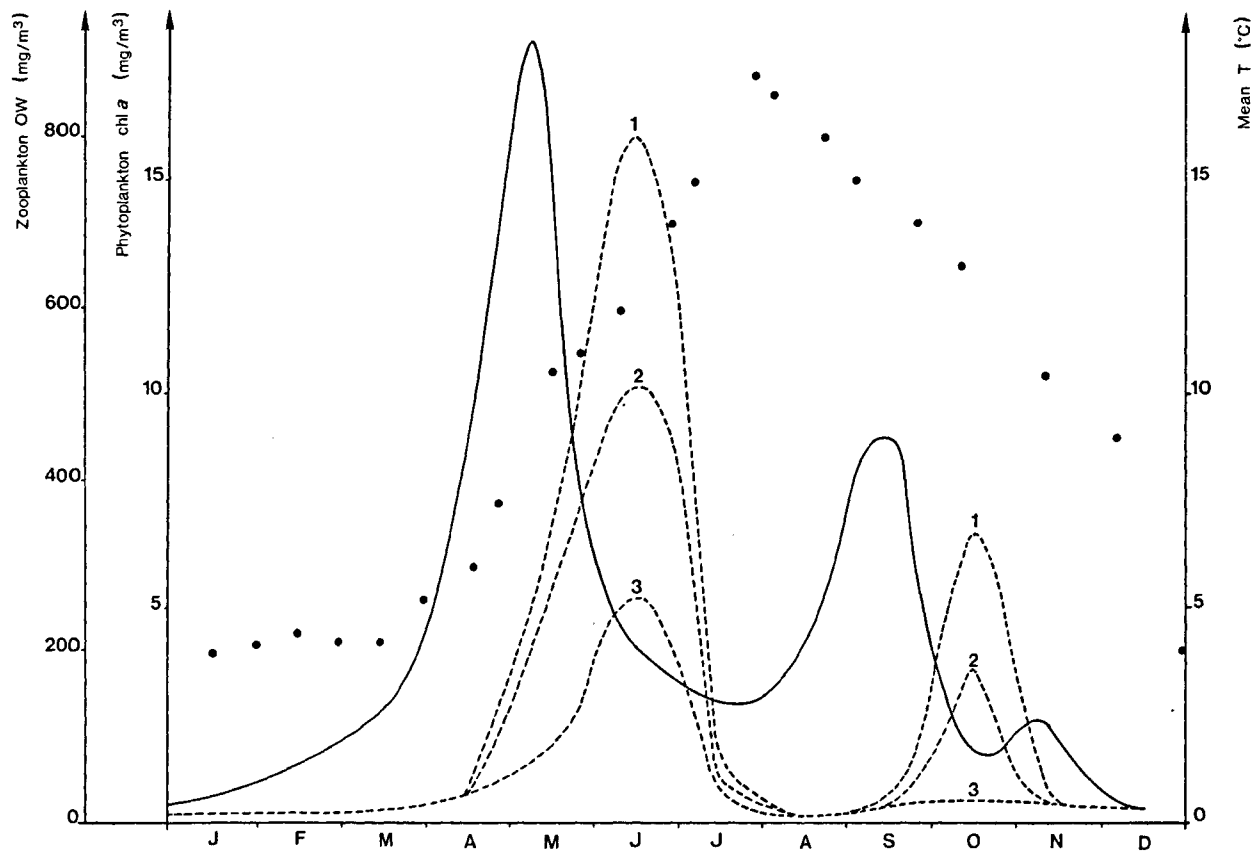
fig. 1.

Zooplankton (dotted line) and phytoplankton (continuous line) biomassa evolution along the Belgian coast in 1979.
Curve 2 represents mean values of the whole network and curves 1 and 3 respectively the offshore and coastal ones.
Points represent mean temperature values.

high zooplankton biomass (OW) offshore (797 ± 177 mg OW/m^3) and a lower one along the coast (252 ± 120 mg OW/m^3).

On the other hand, the chlorophyl data are maximum along the coast and especially near the Scheldt estuary (6 mg chl a/m^3).

Moreover, both phytoplankton and zooplankton show a gradient from the coast to the open sea, positive for zooplankton and negative for phytoplankton (fig.2).
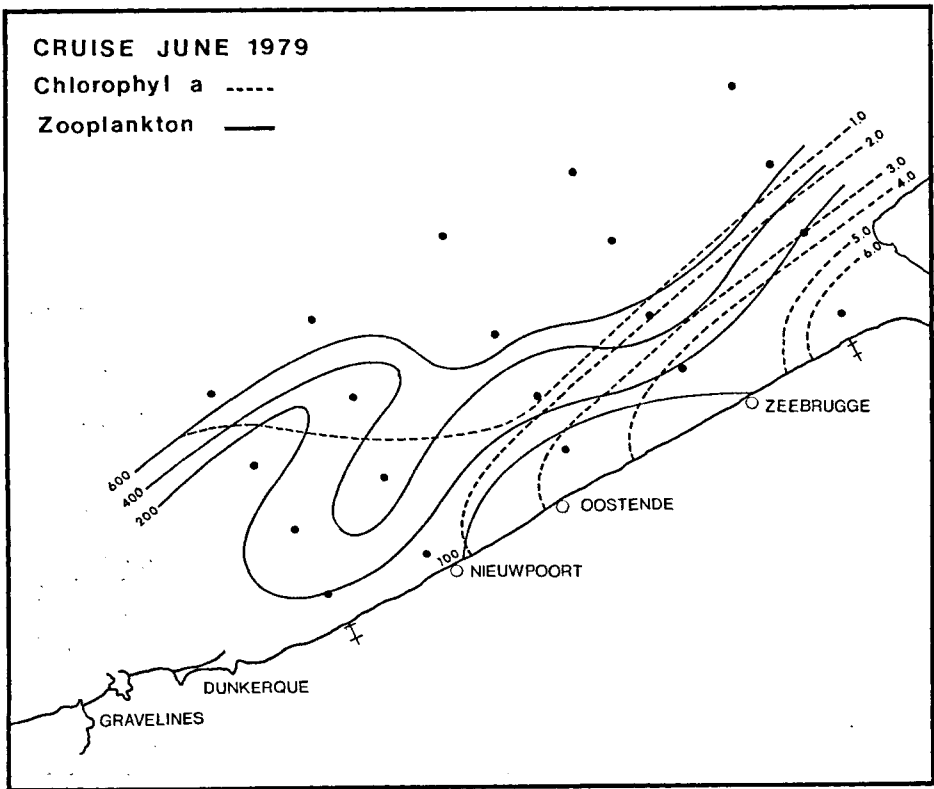

fig. 2.

Zooplankton (mg OW/m^3) and phytoplankton (mg chl a/m^3) biomassa.
The sampling stations are represented by points.

The offshore area presents higher biomass variations than those in the coastal one : during the spring bloom, the offshore zooplankton averages reach 800 mg OW/m^3 and the coastal one 250 mg OW/m^3. The autumn bloom is only observed in the offshore area (250 mg OW/m^3) and remains negligible at the coast (fig.1, curves 1 and 3).

Apart these two maxima, the whole network is homogeneous and zooplankton biomassa remain negligible.
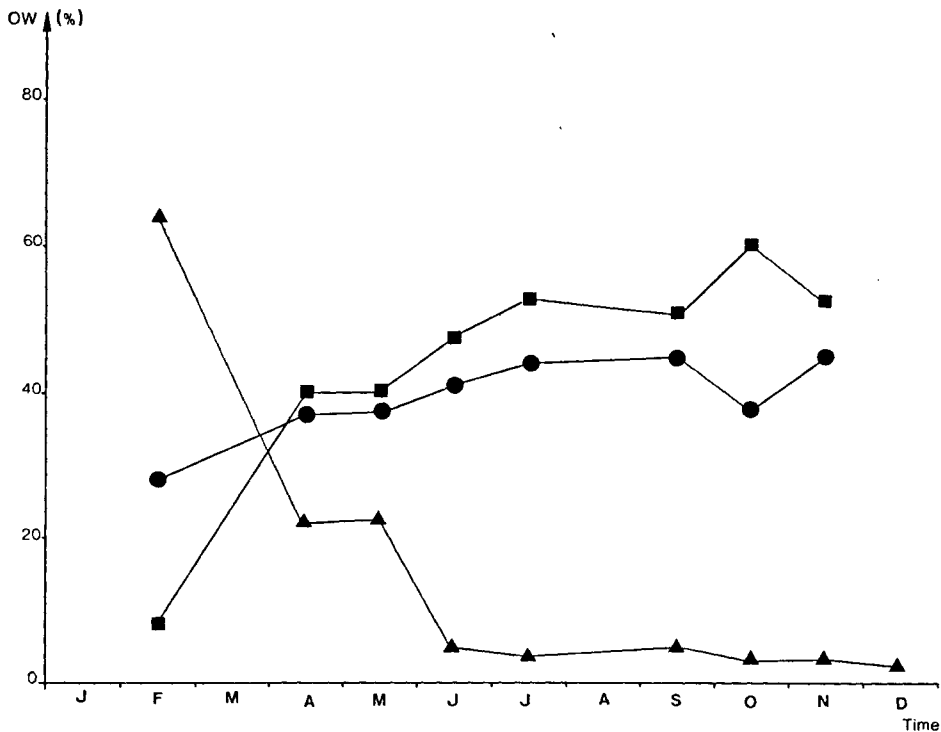

fig. 3.

Monthly mean value of proteins (●), carbohydrates (▲) and lipids (■) expressed in % of the total organic matter (OW)

Zooplankton biochemical content is presented in figure 3. Average pro-tein amount is more or less constant during the whole year (35 - 45 %). Carbohydrate concentrations, very important in April-May (20 to 30 % of OW)

fall to about 3% in June and remain so. Lipid content increases from February to October and afterwards decreases (the too small number of winter data prevents us from formulating any relations to the carbohydrate content).

At a spatial point of view, lipid repartition is rather homogeneous offshore and along the coast (for example 52% in June) ; but the higher contents (65%) are always observed on the front separating these two areas ; protein contents are rather constant. Along the coast, the higher carbohydrate contents are due to the greater concentration of the phytoplankton.

Discussion and conclusions

All the quantitative results of our cruises show once more the existence of the bimodal phyto-zooplanktonic cycle which is characteristic of the temperate seas (Hecq (1975)). If mean values are considered on a large area and during a whole year, a quantitative relation can be drawn between the phytoplankton bloom and the following zooplankton one.

However these two peaks appear within a delay of one month at least ; moreover zooplankton and phytoplankton spatial distributions are different and even show an exclusion which could let us suppose that herbivorous nutrition prevails only along the narrow front. Furthermore important local variations surimpose to the global annual variation of lipid content and reveal maximal lipid stockage in the front area and thus a higher nutritional activity. This area disposition is related to the hydrological flow off the belgian coast (Nihoul and Ronday (1974a, 1974b), Hecq (1979)) : water coming from the Scheldt and loaded with nutrients, is carried away to the South in a residual gyre.

Total carbohydrate content is constant from June on (± 3 %) according to the literature (Raymont and Conover (1961), Mayzaud and Martin (1975), Båmstedt (1978), Gaspar and Hecq (1980)). However in the early spring this content is exceptionally high at the coast (20% of OW) and is likely to be related to phytoplankton which can represent up to 40 % of the sample.

The whole results show that in the early spring, when the phytoplankton peak reaches its maximum, total animal biomass is low and its proteins represent a high percentage of the organic weight. Feeding would be directly used either for proteogenesis (growth) or for reproduction (increasing of indivi-

duals number) ; furthermore respiratory metabolism is very high at this period (Hecq (1973)). Later on, at the end of the bloom, the zooplankton biomass reaches its maximal value and then decreases ; lipid amount goes on increasing (up to about 50% of the OW). Respiratory quotient, although lower than in bloom beginning, however presents a higher value than the grazing one ; phytoplankton biomass is moreover low. During this period animals would call upon other food sources. Animals become less numerous but contain more lipids.

This situation is comparable to the Korsfjorden (Norway) one (Båmstedt (1978)) : the Copepod *Chiridius armatus* has a constant carbohydrate amount during the whole year whereas lipid concentration presents variations bound to the bloom peaks : lipid content regularly decreases from October on and again increases at the spring beginning. The author suggests that these variations are linked to trophic phenomena. Individual average lipid amount decreases from August to March and this decrease is on direct opposition to the protein amount.

Conover and Corner (1968) have analysed lipidic content of *Calanus finmarchicus* and *Metridia longa* collected from September to May in the Gulf of Maine : the values for the herbivorous species *Calanus finmarchicus* are always higher than those of the carnivorous species *Metridia longa* ; in both cases, lipids progressively decrease during winter.

Moreover, Corner and Cowey (1968) and Lee *et al.* (1971) have shown that lipid consumption coefficient is variable : *Calanus finmarchicus*, which can stock lipids up to 40% of its dry weight, only uses 1 to 2% of these lipids daily during an experimental fast whereas an omnivorous species such as *Acartia clausi* uses up to 60% of its lipid weight during the same period. Therefore it seems that lipid combustion is more rational in herbivorous than in carnivorous Copepods.

In conclusion, trophic relations could be generalized as follows (fig.4). During phytoplankton maxima, low amounts of zooplankton feed mostly on vegetals (important grazing) and their respiratory quotient is high (>1 mg C/mg C/ D) : a great part of ingested energy (carbohydrates) is used for protein production (growth and reproduction)(=phase 1). During this period, amylase activity would be the greatest ; Boucher and Samain (1974) have stressed the close relationship between grazing and amylase activity.
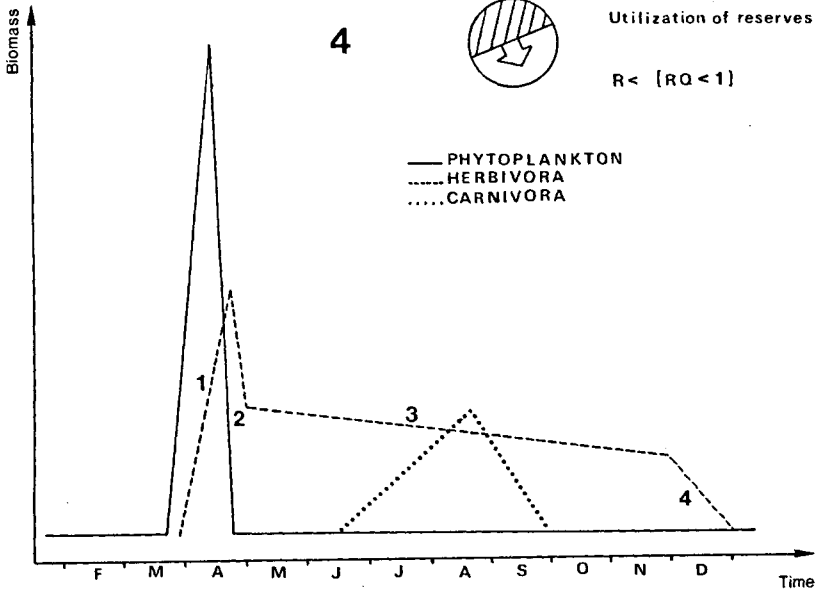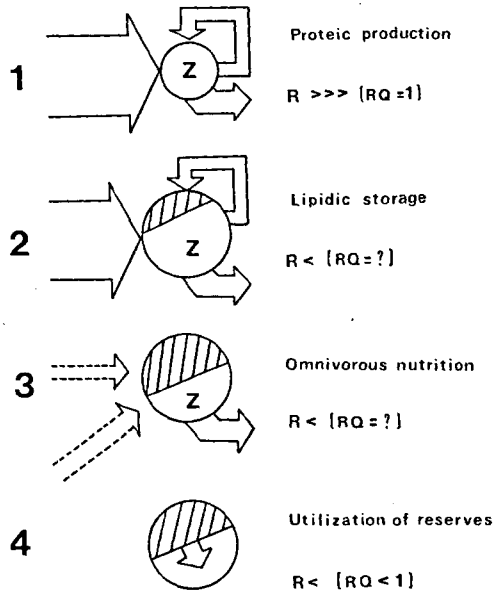
fig. 4.

Schematization essay of phyto/zooplankton relations in the Southern Bight of the North Sea
(explanations in the text)

After phytoplankton maximum, herbivorous zooplankton reaches its maximum biomass and begins to store lipids (phase 2). The latters are stored as droplets containing mainly long chains of polyunsaturated fatty acids (Chapelle *et al.* (1979)).

After phytoplankton disparition, herbivorous zooplankton would modify its enzymatic composition, making itself able to use another source of food *e.g.* living or non living either dissolved or particulate organic matter, resulting from phytoplankton decay, or from any exogeneous origin (phase 3). And finally, during winter, as food is lacking, animals would use their lipid stock (phase 4). The lipid consumption of the herbivora would be adaptative, as during the fast periods, the zooplankton is brought to utilize very progressively its lipid stock elaborated during the phytoplankton peaks.

By integrating phytoplankton and zooplankton stocks and flows during these four periods, global relations can be balanced, whereas instantaneous relations are positively or negatively out of balance according to the peak periods. This diet modification during the life of an organism was demonstrated at the higher trophic level of *Palaemon serratus*, the amylase activity of which quickly reaches a high level during the 2^d Zoe stage whereas proteolytic activity appears only in the 5th Zoe stage (Mysis stage) (Darnell (1958), Pandian (1969)). During summer, herbivorous biomass decrease can be connected to the carnivora appearance. In June, the carnivora are represented by the Cladocera *Evadne nordmanni*, *Podon leuckarti* and *Podon intermedius* (Hecq (1976)) ; after the autumn bloom appear Chaetognatha (*Sagitta setosa*) (Hecq (1976), Hecq *et al.* (1976), Hecq (1979)) which have an important proteasic activity (Boucher *et al.* (1975)).

For a better understanding of this somewhat simplified scheme, we shall try to define diet alternation by nutritional measurements on different substrates, by detailed analysis of the biochemical composition during the peaks and especially by measurements of the carbohydrasic, lipasic and proteasic activities.

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