C.I.P.S.

MODELE MATHEMATIQUE DE LA
POLLUTION EN MER DU NORD.

TECHNICAL REPORT

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DYNAMIC BEHAVIOUR OF NUTRIENTS

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1) Introduction

This report presents a study of nutrient equilibria in the Southern Bight of the North Sea. The year 1974 was devoted to frequent nutrient sampling of five priority sites with additional measurements during biologically important periods.
In view of the atmospheric conditions, only two points of zone 1 South (01 and 55) were regularly visited and therefore only this last zone will be represented here.

The annual evolution of dissolved nitrate and nitrite represents in zone 1S a regular pattern since 1971, maxima around March and minima from June to September (fig.1). This evolution is the same for zone 1 North and zone 2, only the magnitude of the concentrations beeing changed.

From 1974, nitrogen, as ammonia, was determined routinely. Figs. 2 and 3 represent the annual cycle of total dissolved nitrogen (NO_2^-, NO_3^- and NH_4^+) and ammonia for zone 1S (each value represented is corrected for sample depth)(I.Elskens and D. Janssen 1974).

2) Discussion

a) Biological Utilization of Nitrogen Nutrients

Nitrate and nitrite normally show a regular increase in concentration through April-May when a sharp drop-off is observed. Up to this year, the disappearance of the two anions has been attributed to a biological uptake taking place in the zone and resulting from the spring phytoplanktonic bloom.

Many factors now indicate that in fact, only ammonia provides the nitrogen necessary for this phenomenum.

It is known that most marine species prefer to incorporate ammonia for the production of protein since nitrates have first to

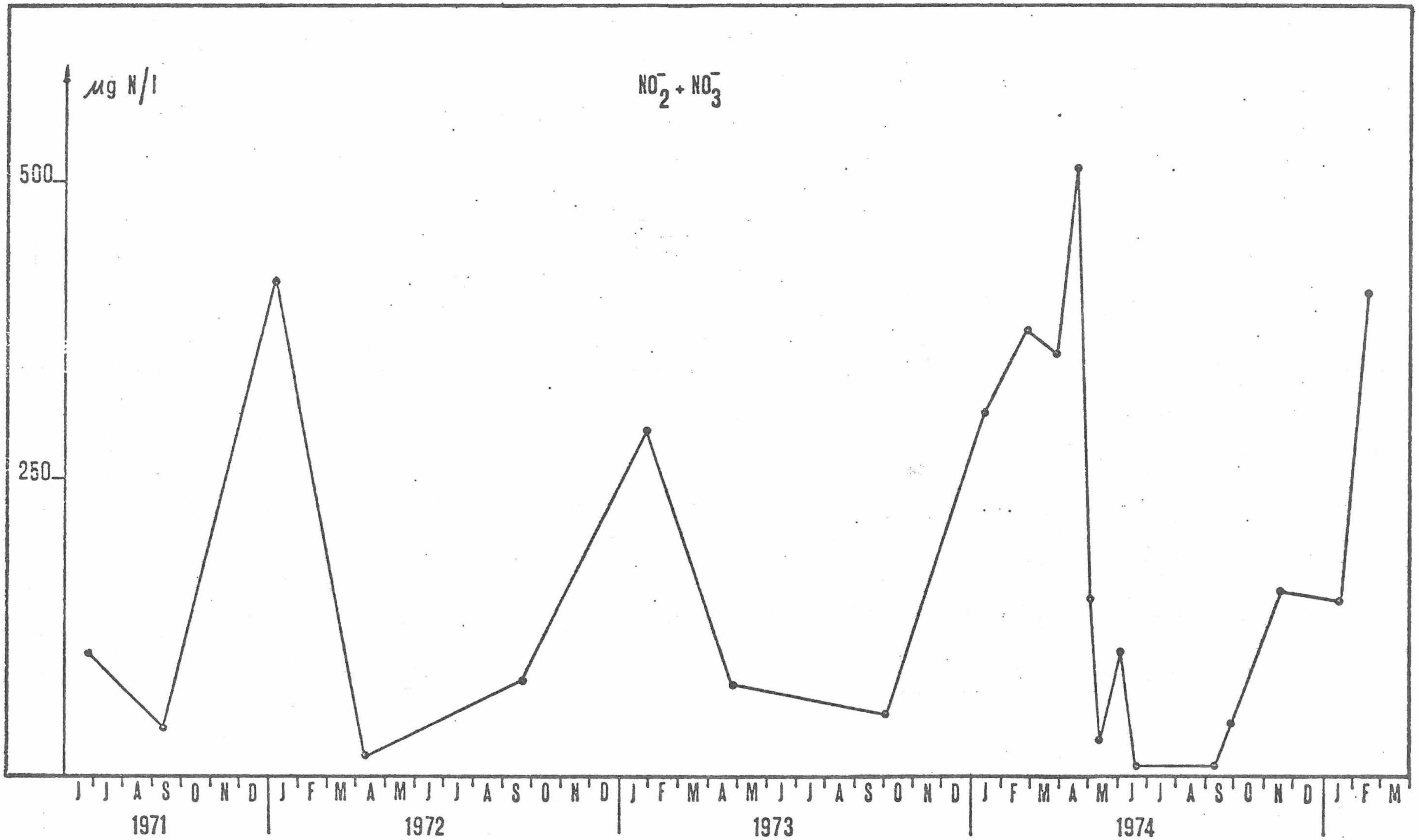

Fig 1: ANNUAL CYCLES OF DISSOLVED NITRATE AND NITRITE IN ZONE 1 S.

Fig 2: TOTAL DISSOLVED NITROGEN IN ZONE 1 S.

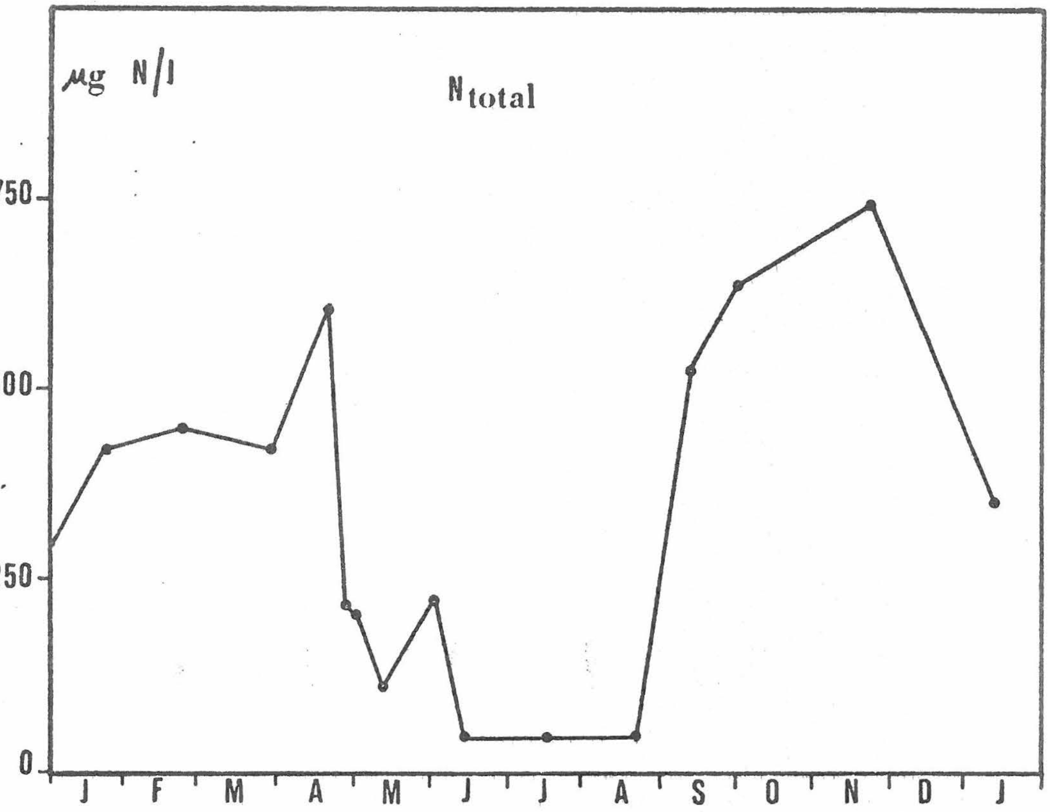

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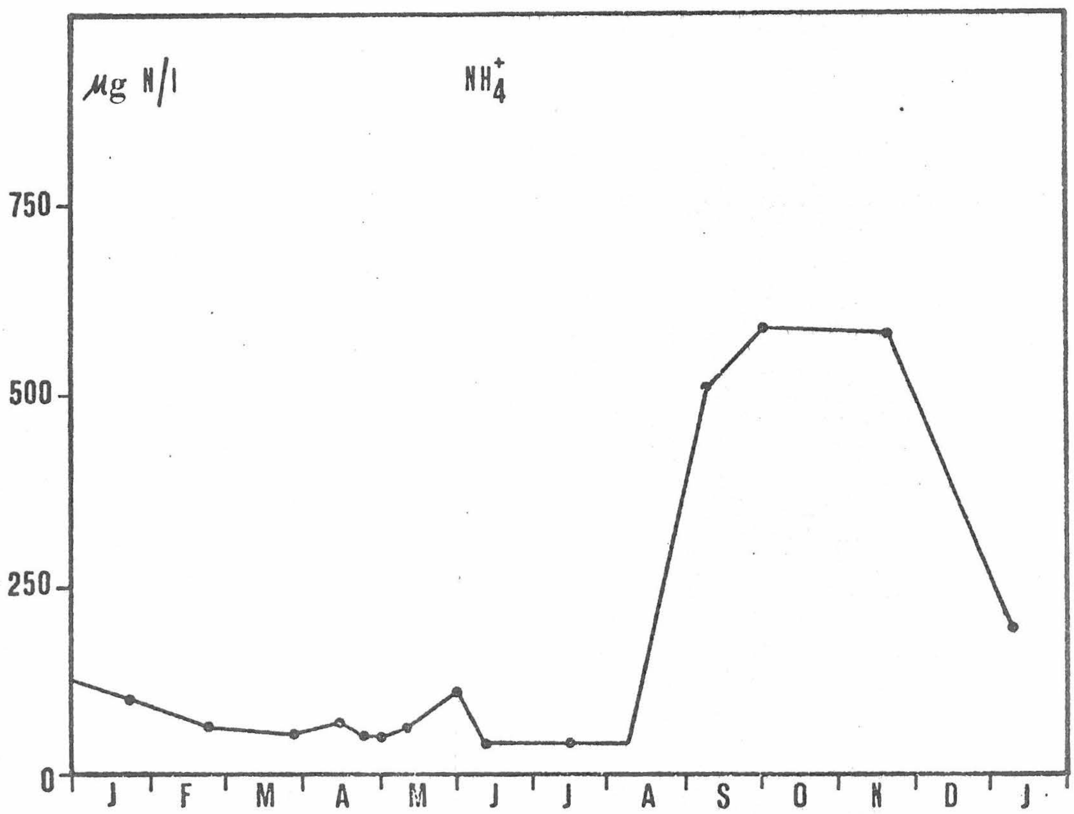
Fig 3: DISSOLVED AMMONIA IN ZONE 1 S.



be reduced to ammino nitrogen (Helder 1974). This reduction is carried out by an enzyme inhibited by ammonia. For concentrations of NH_4^+ >28 μg N/l this inhibition is maximal. The kinetics of nitrogen incorporation (as NO_3^- or NH_4^+) obey the Michaelis-Menten relationship with a maximal uptake for concentrations >14 μg N/l. The available nitrates will only be used to insure maximum growth if the amount of ammonia falls below this value.
Since during the year the ammonia concentrations are never lower than 30 μg N/l, there is sufficient NH_4^+ to insure primary production by this mechanism.

In fact, the measured phytoplanktonic primary production can not be used to explain the sudden fall of dissolved nitrogen in the spring. From primary production measurements (Mommaerts 1974) the uptake of nitrogen can be estimated at more or less 5 μg N/l-day during the month of April, which gives a fifteen day consumption of 75 μg N/l. This value is quite different from the 500 μg N/l we found in this study. On the other hand, the evolution of productivity (i.e ratio of primary production to biomass) which can not be connected to the nitrate concentration, is strongly correlated to the amount of dissolved ammonia (Mommaerts).

Moreover the computation of nitrogen flow as NO_3^- and NH_4^+, coming from the South border of the zone and going out through the North border (figs. 4 and 5), reveals that the amount of nitrate eluting from the Channel from the end of April through summer is already low and is increased as it passes the North border with coastal and estuarian wastes.
On the other hand, ammonia appears to be consumed and/or transformed into NO_3^- by nitrifying bacteria during the summer months.

Important seasonal nitrate cycles are therefore mostly the consequence of phenomena taking place before water masses flow through zone 1S and not inside the zone.
Nitrate production by the sediments of zone 1S couls also be more important in winter than in summer (Billen 1975) and contribute to the observed cycle.

b) Annual Ammonia Cycle

Evolution of ammonia during 1974 (fig. 3) presents an important peak in autumn (mid-September to mid-December). Few references concerning the ammonia cycle in coastal waters are available.

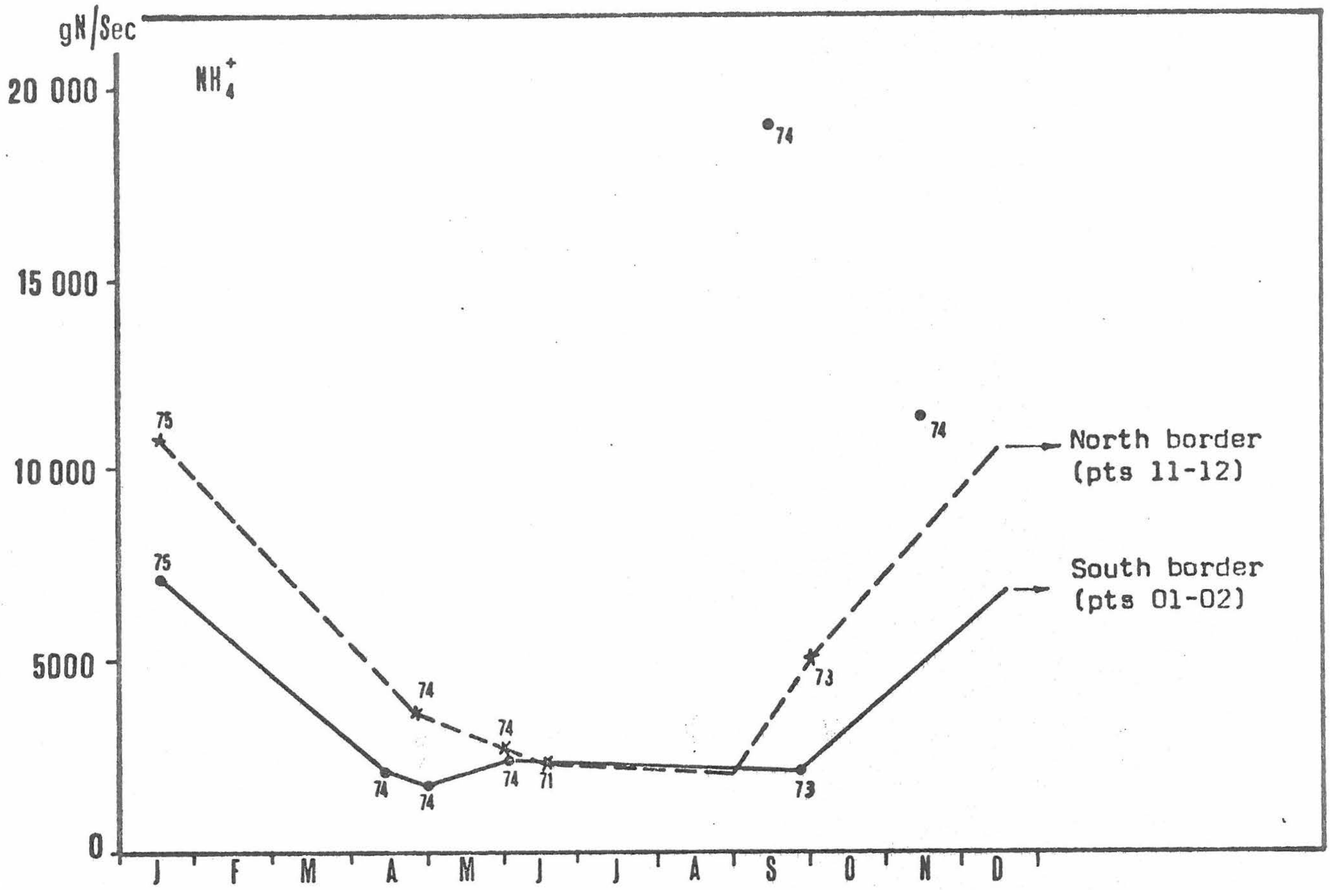
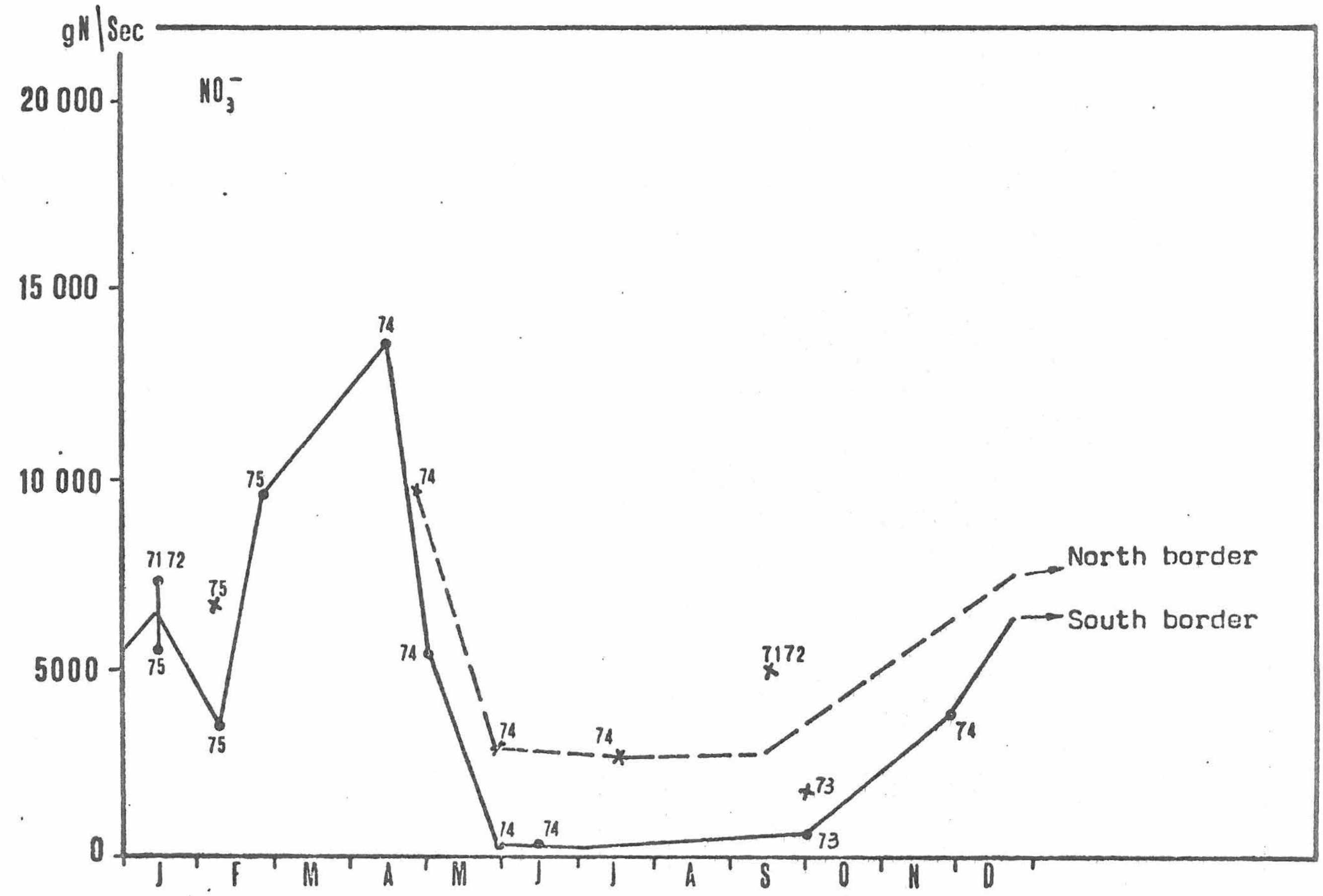


Fig 4: Zone 1 S: AMMONIA INFLOW AND OUTFLOW

Fig 5: Zone 1S: NITRATE INFLOW AND OUTFLOW.



A relevant study was made by Helder (1974) during 1971 and 1972 in the Dutch Wadden Sea. For one station (salinity = 32.58 ‰) used as a reference point for the adjacent North Sea, he obtains a cycle qualitatively very similar to the one measured in zone 1S, showing a maximum from October to January. Quantitatively the concentrations he obtains in summer are of the same magnitude as those of fig. 3. On the other hand the 1974 autumn peak of zone 1S seems to be abnormally high (roughly a factor of 3); however, measurements taken in October 1973 did not show this high peak.

Many factors can be responsible for this situation. The principal effect appears to come from the exceptional climatic conditions during the period. Also coastal wastes are difficult to estimate in view of the sparcity of information about them, contributions of the estuaries and especially of the Scheldt are much better known and one could observe after the torrential rains of the autumn of 1974, a significant increase in the volume of river flow. Indeed, if one estimates mean river flow at 50 m^3/sec, this value was observed to increase during October and November 1974 to approximately 300-400 m^3/sec.

Table I gives values of nitrogen discharged as NO_3^- and NH_4^+ (Billen 1975).

TABLE I

	Flow (m^3/sec)	N_{total} (g N/sec)	NO_3^- (g N/sec)	NH_4^+ (g N/sec)
January 1973	79	774	503	271
May 1973	56.5	498	129	369
September 1973	30.7	86	70	16
February 1974	131	1010	404	606
March 1974	116	844	320	524
October 1974	400	1890	1417	473

These data show that the average ammonia concentration discharged in October 1974 is not abnormally high (altough it is, much greater than the average value for September 1973) because the ideal conditions for nitrification were found in the estuary at this time (i.e fresh water flow, rich in nitrifying bacteria and good aeration of the water). Therefore the amount of nitrate is greatly enhanced. The heavy river flows observed during the autumn of 1974 caused a sort of "cleaning" action which resulted in a dilution of the suspended matter and organic decomposition products in the Southern Bight. During this period greater values of turbidity in Breskens than in Antwerp were observed (Wollast, 1975).

One usually attributes the winter increase in ammonia to the mineralization of organic matter produced during summer. In this case the waste flow coming from the coast, the estuaries (Scheldt, Rhine, Thames) and the Channel, could have induced a significant mineralization. Moreover, during this period an important peak in the number of heterotrophic bacteria was observed which could be an additional cause of this effect (Joiris, 1974).
Even the concentration of nitrate is low compared to that of NH_4^+ which can be explained by the hibernation period experimentally observed during a mineralization reaction before the appearance of NO_3^- (Helder, 1974), keeping in mind the low residence time (20 days) of the water masses in zone 1S.

In the same period the very high measured turbidities resulted in a reduced effective depth for sunlight penetration (for point 01 : 2.5 m euphotic depth in September compared to 9.9 m in July; for point 55 : 3.4 m compared to 8.1 m)(Mommaerts, 1974). This could have suddenly reduced photosynthesis and consequently the uptake of ammonia.

Another cause of the high concentration of ammonia during the autumn 1974 could be its release from the upperlayers of sediments by strong winds, especially in shallow areas such as coastal zones. The mean monthly area flux of wind was equal to 73.675 m^2/sec^2 in August 1974, 191.527 m^2/sec^2 in September and reached 238.013 m^2/sec^2 in December. However, quantitatively this wind action can not represent the primary source of ammonia in the water column. In fact, in zone 2, where the mean depth of 25 meters limits the effect of this process, a peak of ammonia of the same magnitude as in zone 1S was founded.

3) Conclusion

From the different phenomena observed during the year 1974, we may conclude that zone 1S, just as the Southern Bight, is essentially an open system subject to many external influences. These influences determine the amplitude and the nature of the biological and biochemical processes which are taking place in this portion of the North Sea.
Understanding and interpretation of this ecosystem will only be possible after a careful study of the boundary conditions (and their temporal variations) as well as the "history" of the water masses in transit in the region.

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