PARTICLE SIZE SPECTRA OF NON-LIVING SUSPENDED MATTER IN THE SOUTHERN NORTH SEA

by

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CONTENTS

I. Summary

From Coulter Counter data and plankton counts a first approximation of the amount and particle size distribution of the non-living suspended matter in the Southern Bight was obtained. Non-living particles in nearshore (coastal) waters were found to be on the average somewhat finer and better sorted than in offshore (Channel) water. Skewness is smaller in the N-NW part of the Southern Bight.

II. Introduction

Suspended matter in the sea consists of a living (plankton) fraction and a dead fraction (anorganic material plus non-living organic matter). Since the amounts and composition of these fractions vary to a large extent independently, it is necessary for a better interpretation of data and processes concerning suspended material to separate both fractions quantitatively. Especially the separation of dead and living organic matter is of importance and methods to do this have been explored at our institute on the basis of chlorophyll (CADÉE & HEGEMAN, 1974), ATP (MANUELS & POSTMA, 1974) and Coulter Counter measurements (GIESKES, 1972). BUDDING (1974) found that a centrifuge method using Ludox (s.g. 1.4) offers good prospects: in combination with a Coulter Counter it appeared to be possible to obtain particle size distributions of both the living as well as the non-living fraction. This method is being worked out at present within the Eems-Dollard Estuary Project.

Anticipating the results of this, Coulter Counter data and plankton counts obtained by GIESKES on suspended matter collected along the Dutch coast (GIESKES, 1972) and in the Southern Bight of the North Sea, collected within the JONSDAP (Joint Oceanographic North Sea Data Acquisition Programme) program (Gieskes in preparation) were analysed. From these data a first approximation of the particle size distribution of the non-living suspended matter (in the size range 3 to 120 μm) in the Southern Bight was obtained.

Acknowledgements. - Thanks are due to Mr. G.W. Kraay who made the spectrum determinations of the large amount of samples collected during JONSDAP 1973 and Mr. J. Kalf who assisted with the calculations. Dr. J. Duinker and Mr R. Nolting put the weight data used in Fig. 6 at our disposal.

III. Methods

Sampling methods, size determination with the model B Coulter Counter (fitted with 100 μm and 280 μm orifice tubes), and the method of plankton counting and size determination with a Zeiss inverted plankton phase-contrast microscope are described by

GIESKES (1972). The Coulter Counter measurements were carried out in the Laboratory which implies a maximum storage time of several weeks.

The samples were stored, after adding I-KI with glacial acetic acid ("lugol"), in a frigidaire at about 5° C. From the Coulter Counter data for the whole sample, and from the plankton-counts, the particle size distribution of the non-living material was obtained by substraction. The non-living fraction includes however some organisms (such as bacteria), that are attached to the non-living particles. The size distribution thus obtained was drawn on probability-paper and the median (Md), the mean (M), sorting (σ) and skewness (α) were determined following INMAN (1952).

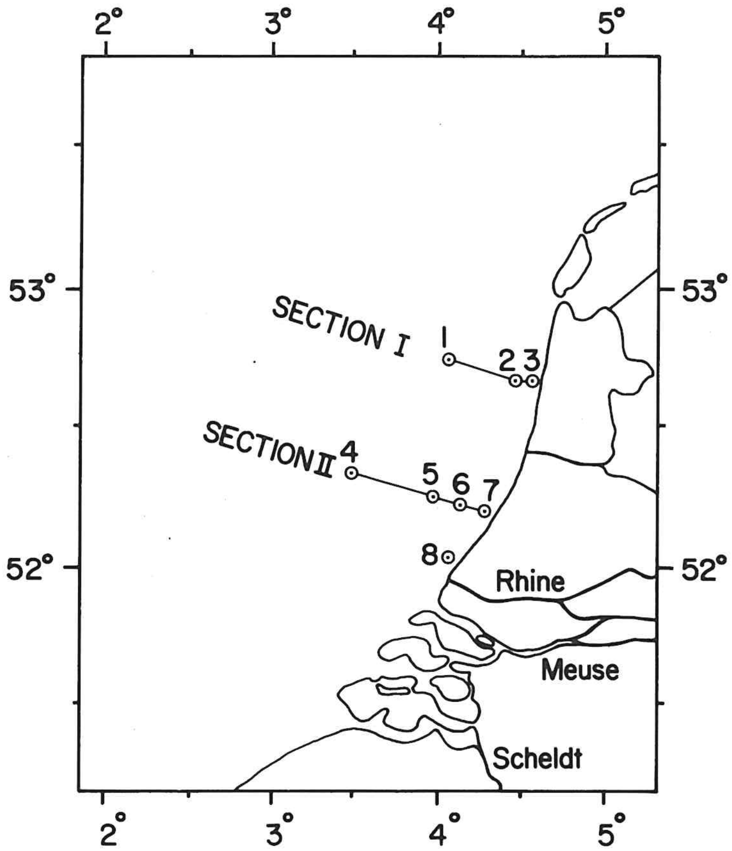


Fig. 1.

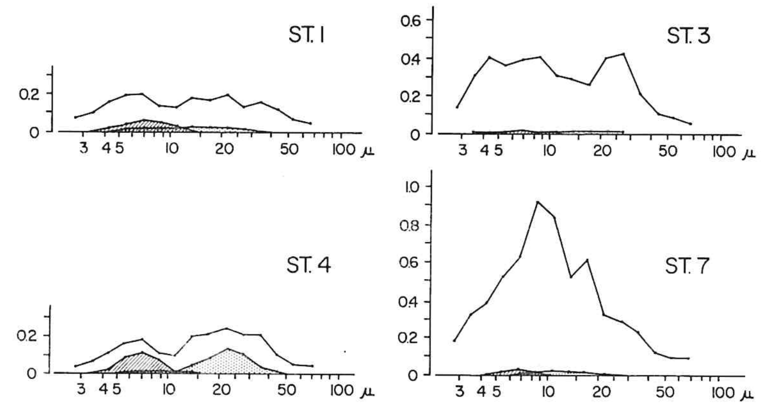


Fig. 1a. Size spectra of suspended particles (surface samples), beginning of March 1971. Abscissa: particle diameter ("equivalent" diameter), log scale. Ordinate: volume of particles (in ppm by volume; 1 ppm = 1 mm^3 per liter). Upper line in each diagram; all suspended particles (both living and non-living). Hatched: μ-flagellates only. Dotted: diatoms only.

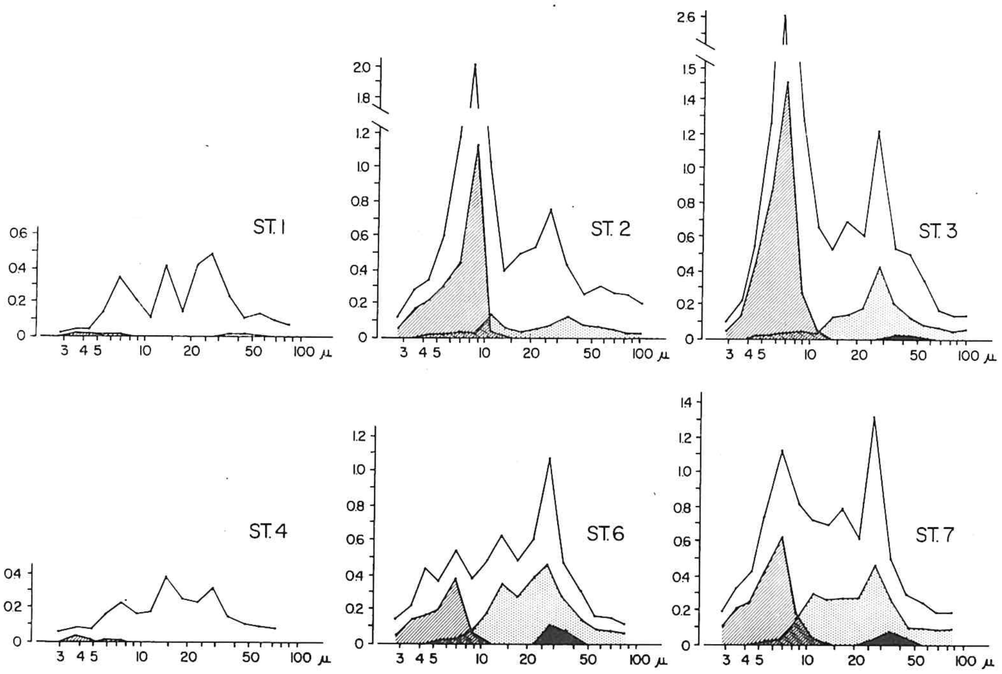


Fig. 1b. Size spectra of suspended particles (surface samples), end of April 1971. Abscissa: particle diameter ("equivalent" diameter), log scale. Ordinate: particle volume, in ppm by volume (1 ppm = 1 mm^3 per liter). Upper line in each diagram: all suspended particles, both living and non-living. Hatched: μ-flagellates only. Dotted: diatoms only. Black: armoured dinoflagellates only.

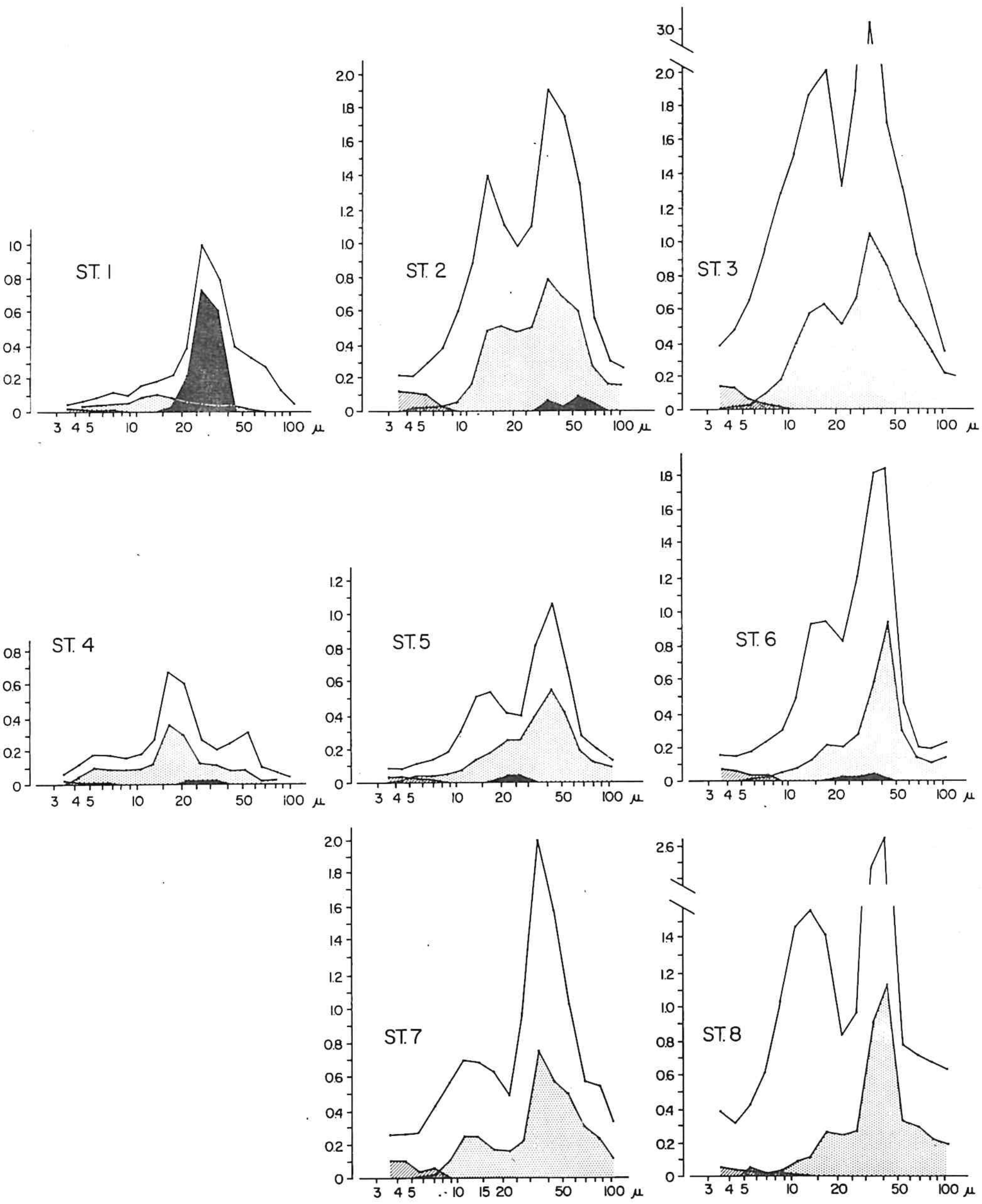


Fig. 1c. Size spectra of suspended particles (surface samples), late-summer cruises 1971. Abscissa: particle diameter ("equivalent" diameter), log scale. Ordinate: particle volume, in ppm by volume (1 ppm = 1 mm^3 per liter). Upper line in each diagram: all suspended particles, both living and non-living. Hatched: μ-flagellates only. Dotted: diatoms only. Black: armoured dinoflagellates only.

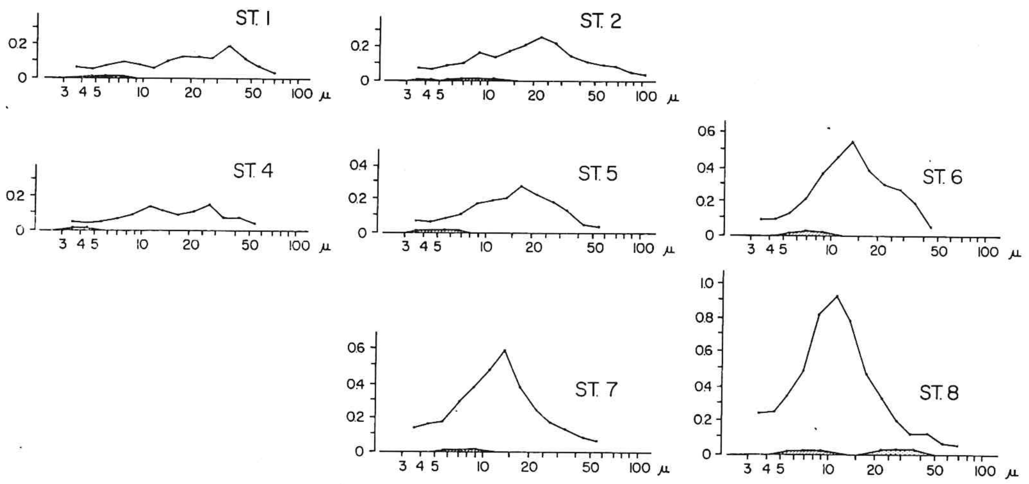


Fig. 1d. Size spectra of suspended particles (surface samples), beginning of November 1971. Abscissa: particle diameter ("equivalent" diameter), log scale. Ordinate: volume of particles, in ppm by volume (1 ppm = 1 mm^3 per liter). Upper line in each diagram: all suspended particles, both living and non-living. Hatched: μ-flagellates only. Dotted: diatoms only.

IV. Results and discussion

Data were used of a number of stations off the Dutch coast which were sampled in March, April, August and November 1971 and of a number of stations in the Southern Bight where samples were collected three times in the autumn of 1973 (JONSDAP-program). The particle size graphs of the 1971 stations are given in Fig. 1a-d and Fig. 2a-d, those of JONSDAP have been omitted because of their number but are on file at the Netherlands Institute for Sea Research. The distribution of the median (Md) of the 1971 samples is given in Fig. 3a-d. the distribution of the grain-size parameters of the JONSDAP samples are shown on the maps given in Fig. 4a-d. The distribution of total amounts of suspended matter in ppm (by volume) is given in Fig. 5, of the non-living suspended matter (in ppm by volume) in Fig. 6; again only particles in the size range 3 to 120 μm have been counted.

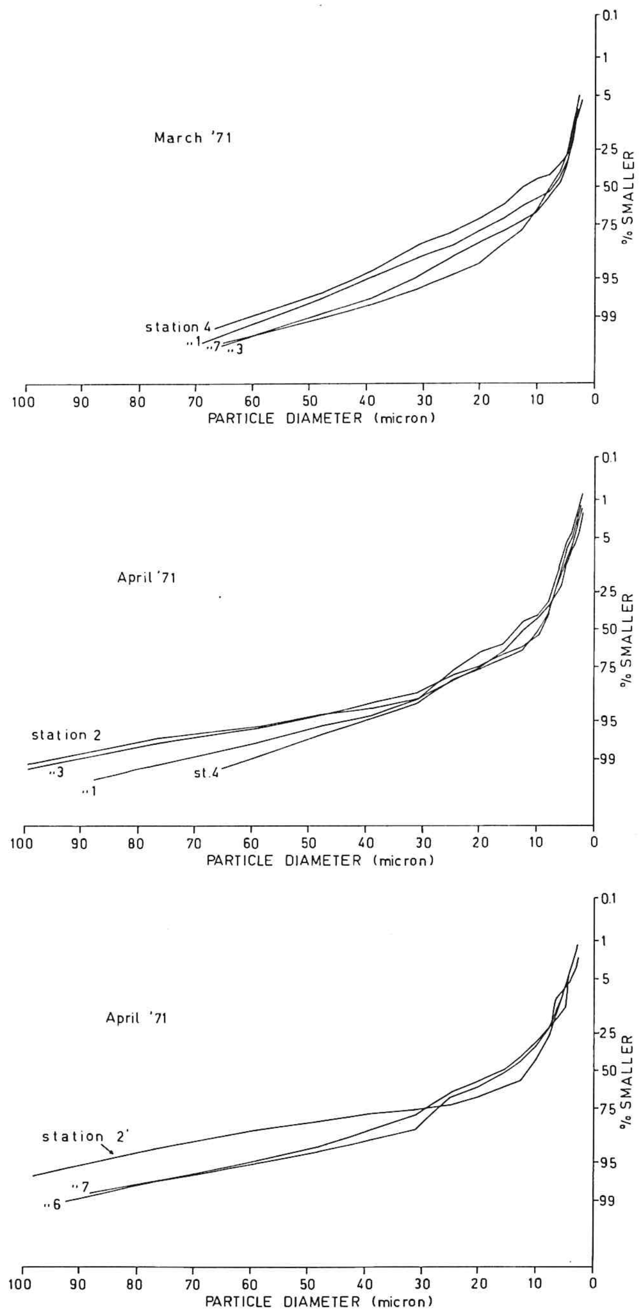
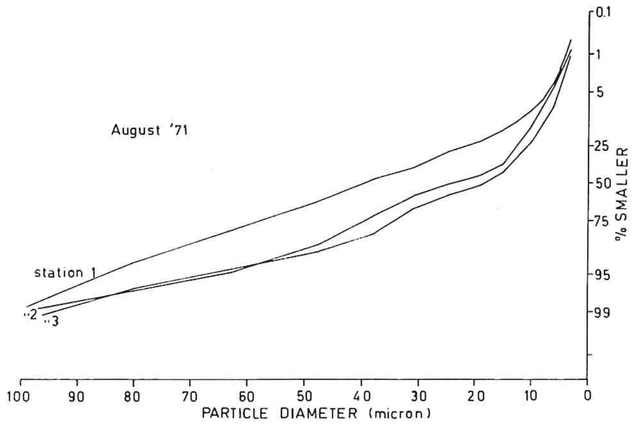
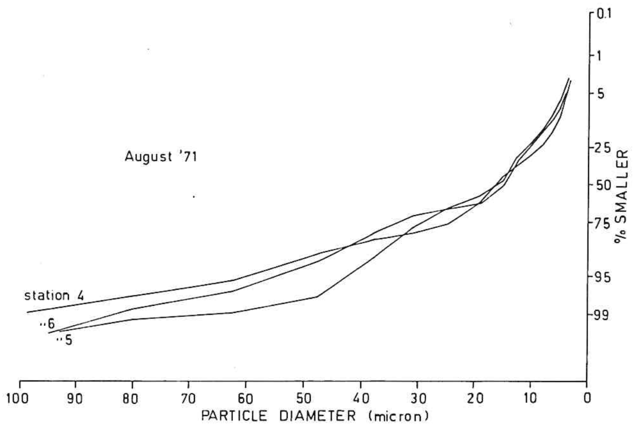


Fig. 2. Cumulative particle size distribution of the non-living fraction of samples collected during the 1971 cruises. See Fig. 1 for location of stations.





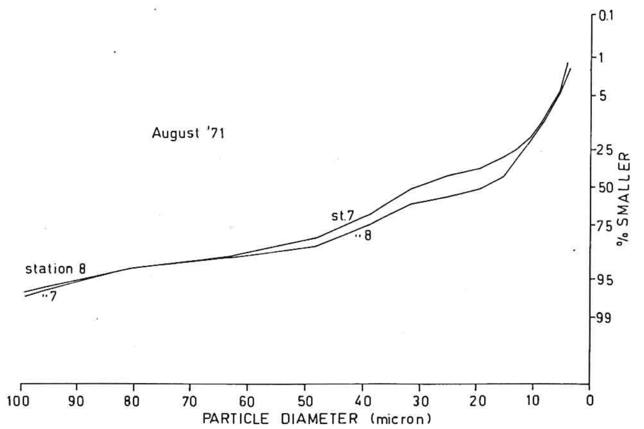


Fig. 2, (Cont.). Cumulative particle size distribution of the non-living fraction of samples collected during the 1971 cruises. See Fig. 1 for location of stations.

Before discussing these results some remarks should be made on the accuracy of the method. Storage of the samples for several weeks may lead to the formation of aggregates which would bias the results towards the coarser sizes. It was found, however, from experiments with water collected in the Wadden Sea that the method of storing the samples and shaking them vigorously before analysing them, resulted after some weeks in about the same particle size distribution. Nevertheless it is advisable to carry out the Coulter Counter measurements directly on board because in some cases storage of samples has

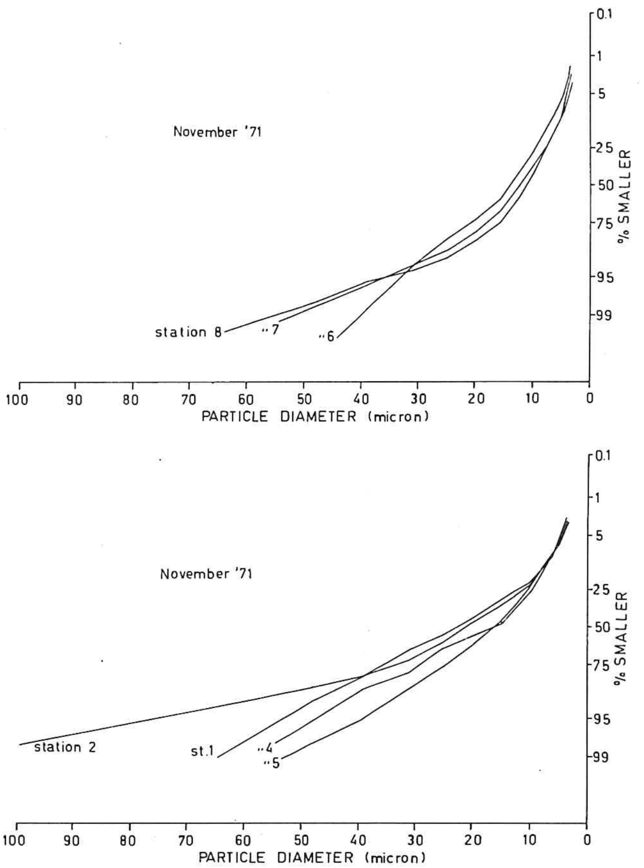


Fig. 2, (Cont.). Cumulative particles size distribution of the non-living fraction of samples collected during the 1971 cruises. See Fig. 1 for location of stations.

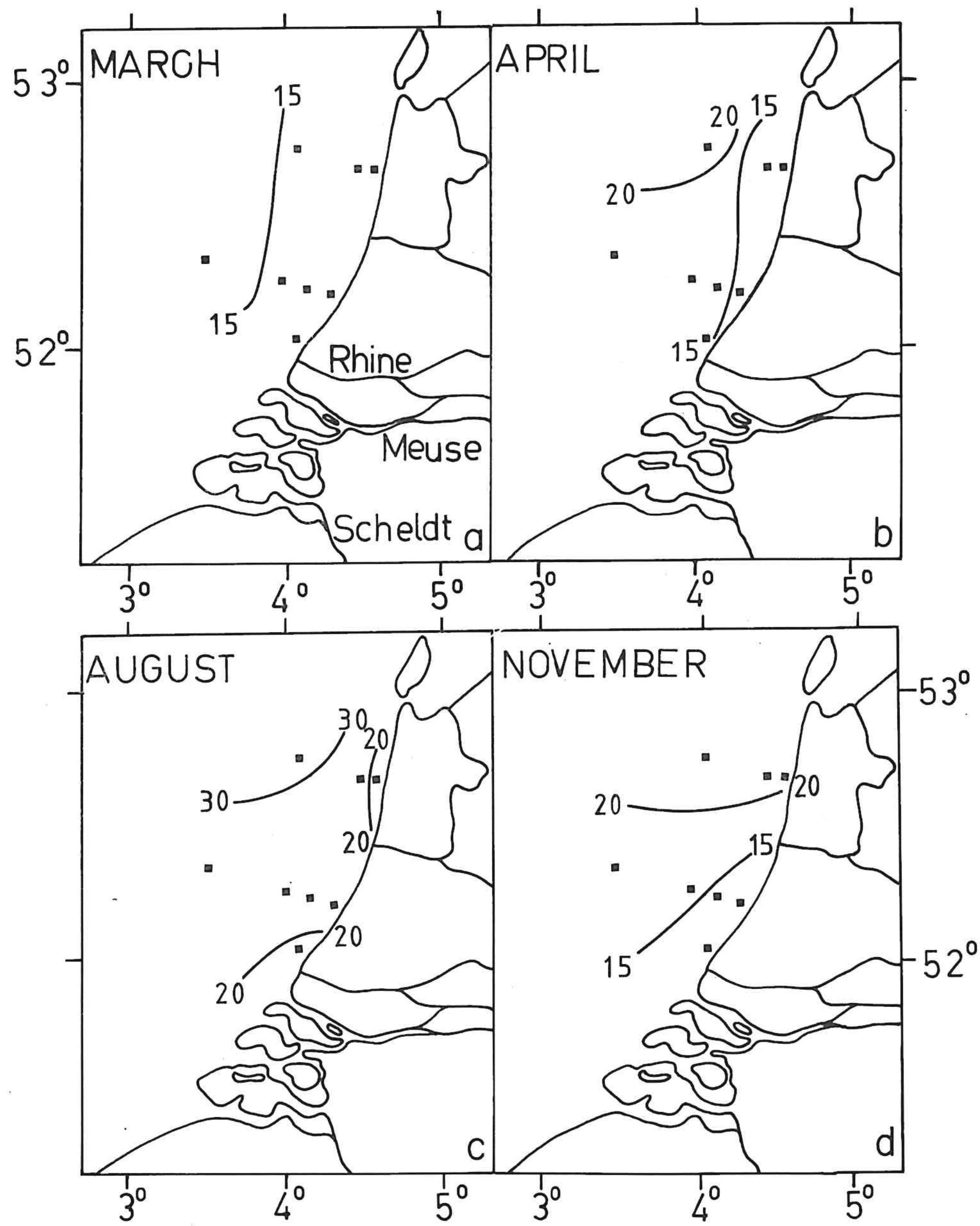


Fig. 3 a-d. Median diameter (in µm) of particle size distributions (size range 3-120 µm) of the non-living fraction, 1971 cruises.

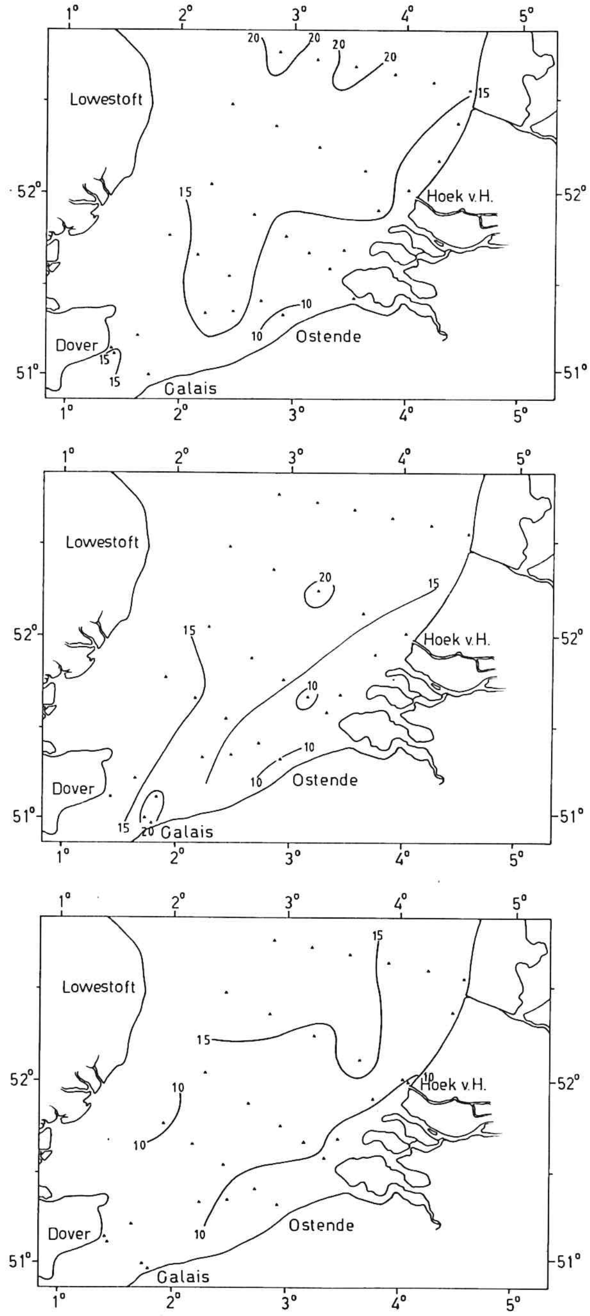


Fig. 4a, 1-3. Median diameter (in μm) of non-living suspended particles in the size range 3-120 μm, JONSDAP cruises 1973. 1. 3-7 Sept. 1973. 2. 1-5 Oct. 1973. 3. 29 Oct. - 3 Nov. 1973.

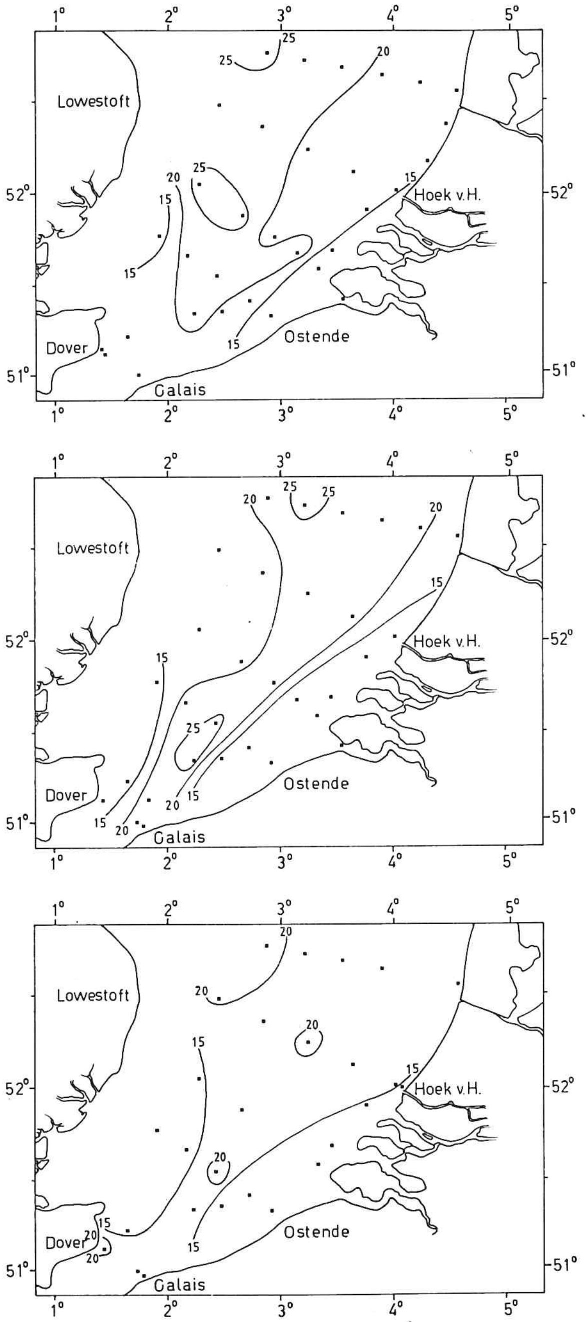


Fig. 4b, 1-3. Mean diameter (in μm) of non-living suspended particles (size range: 3-120 μm), JONSDAP cruises 1973. 1. 3-7 Sept. 1973. 2. 1-5 Oct. 1973. 3. 29 Oct - 3 Nov. 1973.

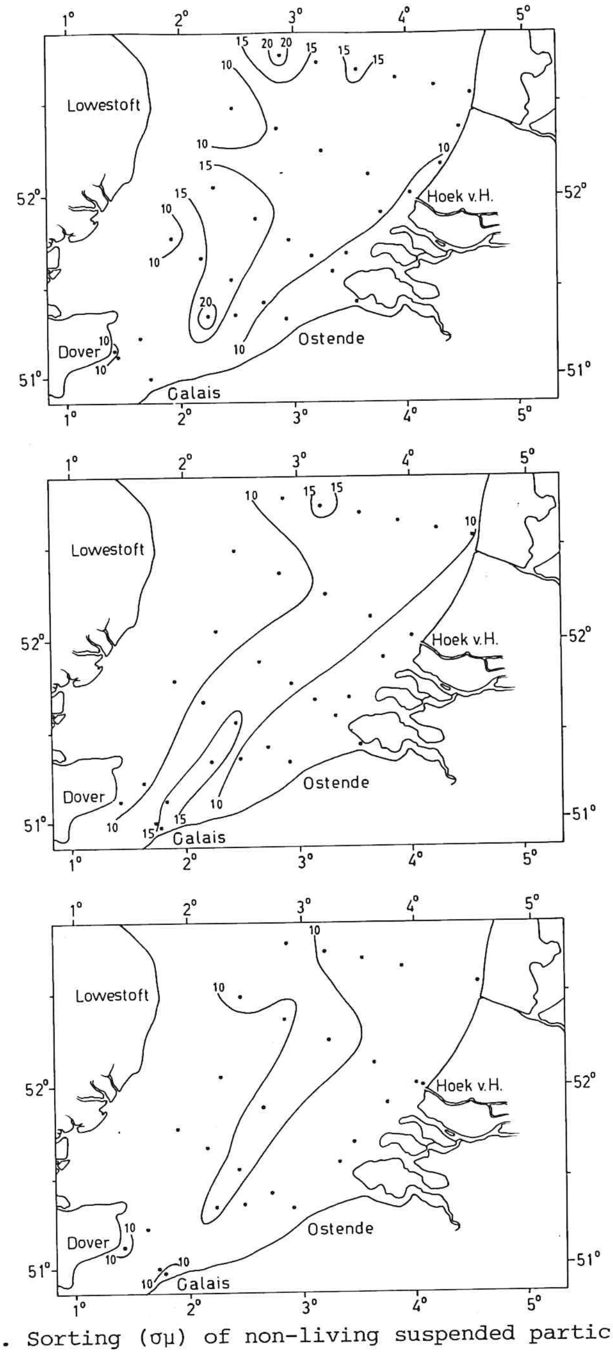


Fig. 4c, 1-3. Sorting ($\sigma\mu$) of non-living suspended particles in the size range 3-120 µm, JONSDAP cruises 1973. 1. 3-7 Sept. 1973. 2. 1-5 Oct. 1973. 3. 29 Oct. - 3 Nov. 1973.

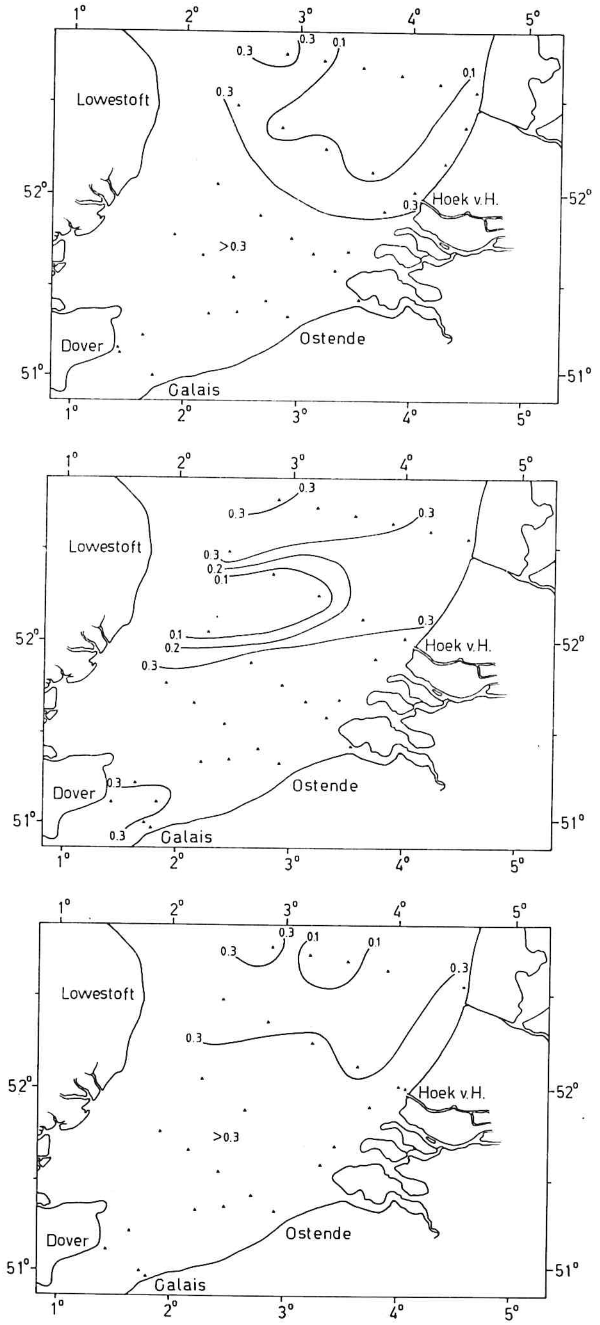


Fig. 4d, 1-3. Skewness ($\alpha\mu$) of non-living suspended particles in the size range 3-120 µm, JONSDAP cruises 1973. 1. 3-7 Sept. 1973. 2. 1-5 Oct. 1973. 3. 29 Oct. - 3 Nov. 1973.

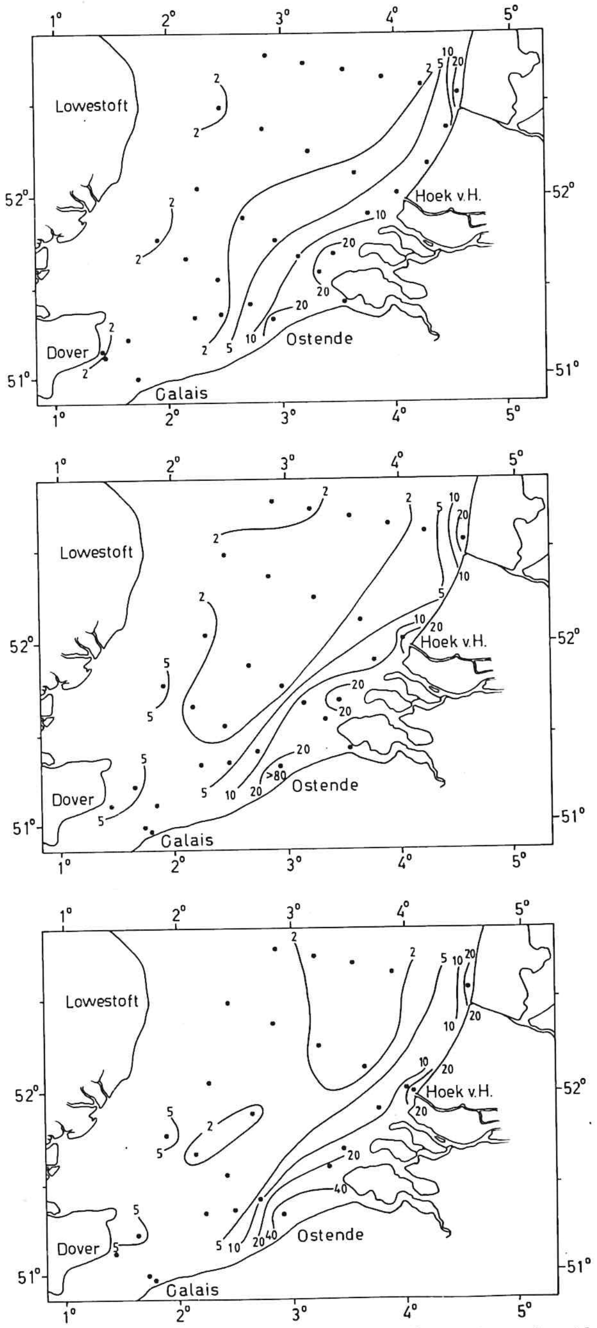


Fig. 5 a-c. Distribution of total suspended matter in the size range 3-120 µm, in ppm (by volume; 1 ppm is 1 mm^3 per liter) during JONSDAP cruises 1973. a. 3-7 Sept. 1975. b. 1-5 Oct. 1973. c. 29 Oct. - 3 Nov. 1973.

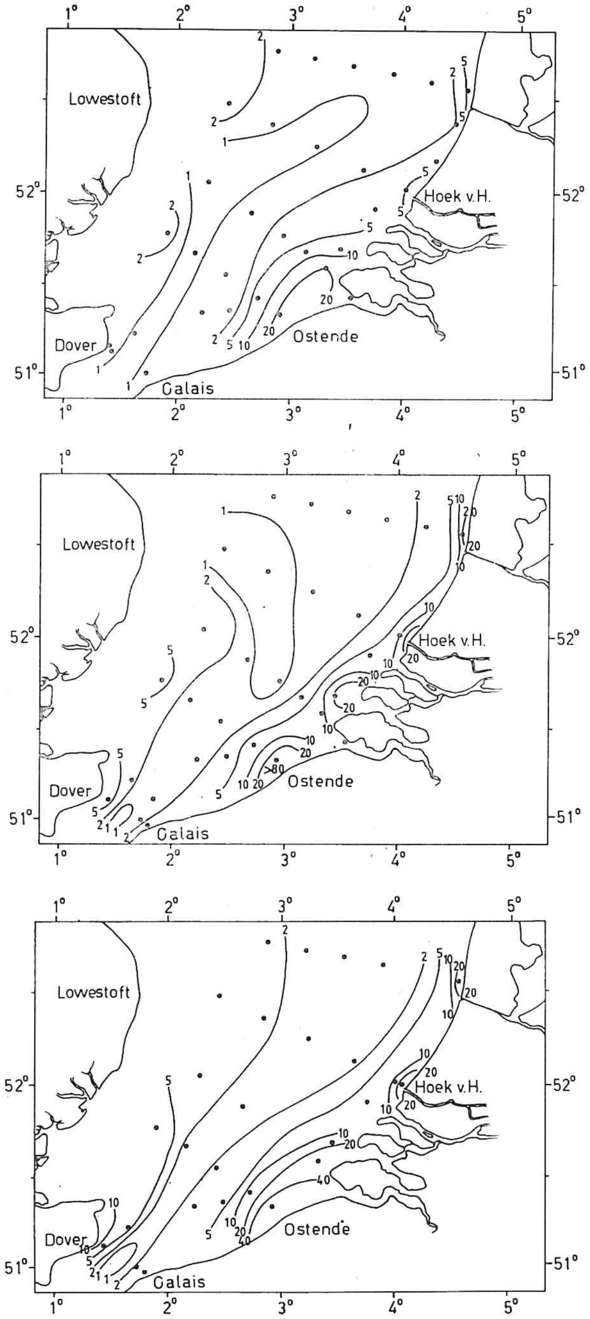


Fig. 6 a-c. Distribution of non-living suspended matter in the size range 3-120 μm, in ppm (by volume; 1 ppm = 1 mm^3 per liter), JONSDAP cruises 1973. a. 3-7 Sept. 1973 b. 1-5 Oct 1973. c. 29 Oct. - 3 Nov. 1973.

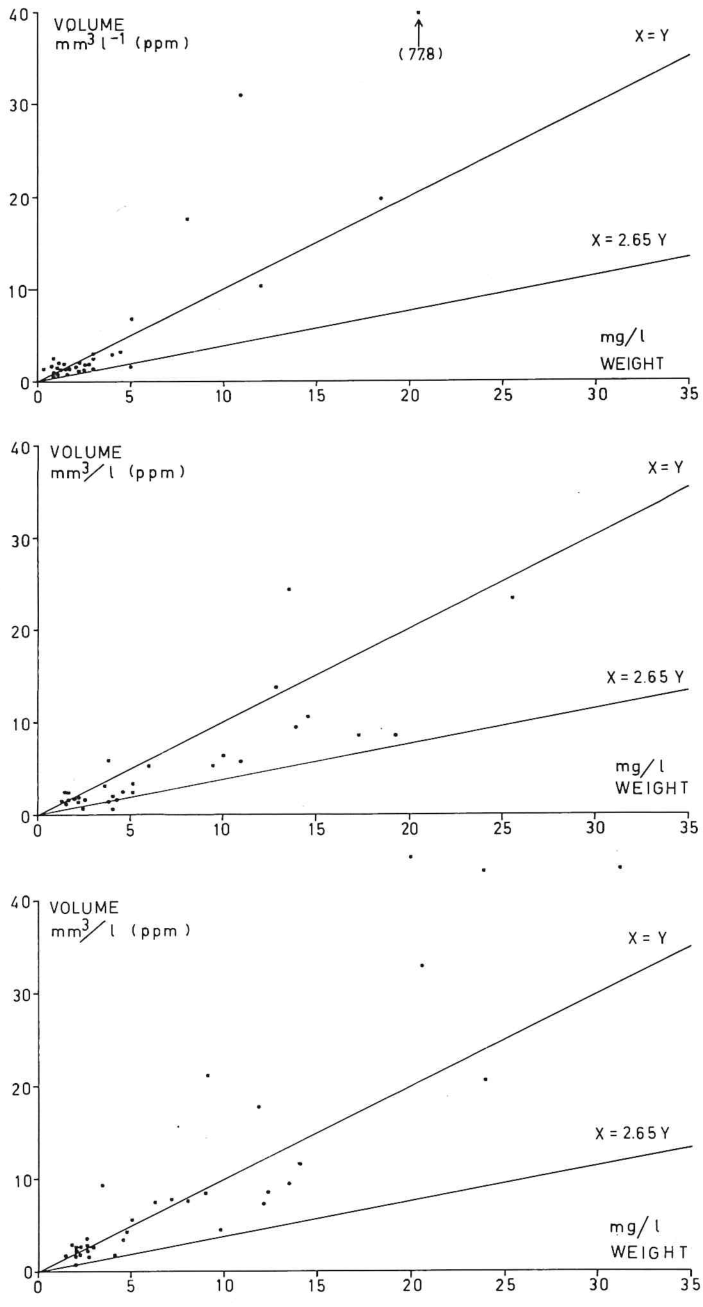


Fig. 7, a-c. Relation between volume (in ppm, i.e. in mm^3 per liter) and weight (in mgr. per liter) of total suspended matter. a. 3-7 Sept. 1973. b. 1-5 Oct. 1973. c. 29 Oct. - 3 Nov. 1973.

led to arbitrary results (MANUELS, personal communication). Also the plankton counts may be biased because to some extent they depend on the operator who has to estimate the equivalent diameter of the plankton particle. The total volume of phytoplankton estimated in this way, however, shows a neat relationship with chlorophyll content (GIESKES, 1972) and the peaks, present in most plankton size distributions obtained from the plankton counts, coincide with those found with the Coulter Counter. Finally the cumulative grainsize curves found for the non-living material are of the shape one would expect for suspended material (DOEGLAS, 1946) and the results of repeated sampling are consistent. The results obtained here are therefore considered to give a resonable first approximation of particle size distribution in the Southern Bight. In comparing the data presented here with grainsize of e.g. bottom sediments obtained in the usual way (pipette-method of Atterberg-Robinson method) it should be realised that the method used here gives the total volume for a given particle-size interval, not total weight.

In Fig. 7 the total weight of the suspended material > 0.45 μ is put against the total volume as determined with the Coulter Counter. Assuming the inorganic detrital particles to have an average s.g. of 2,65 and the organic material to have s.g. of near to 1.0 the points should fall between the lines $x = y$ and $x = 2.65\ y$, as suspended material is a mixture of both. Apart from one point (which is assumed to be erroneous) there are no points that fall well below the line $x = 2,65\ y$ but a considerable number of points fall above the line $x = y$. As particles with a s.g. $<$ 1.0 will not remain in the water but float to the surface, there are apparently a number of particles which contain much organic matter and water and have an inflated structure so that their apparent volume measured by the Coulter

Table I

Size-parameters of the 1971 samples.

	Md	M		
March	10.5-19.0	13.6-21.8	8.6-16.6	0.17-0.52
April	14.0-20.5	18.7-25.4	11.8-18.1	0.10-0.60
August	18.5-39.0	24.2-40.8	14.0-26.2	-0.01-0.51
November	11.5-22.2	13.2-26.0	6.8-18.0	0.21-0.41

Counter is much larger than the total volume of the solid matter in the particle. Aggregates, but possibly also dead diatom frustules may have such a structure.

The data for 1971 (Fig. 3; Table I) shows that the median diameter tends to be between 10 and 25 µ throughout the year: only in August 1971 the Md was higher in all samples (up to 39µ). In that period also the amount of diatoms (peak diameter 30 to 40 µ) was very high in the samples which suggests that the large median diameters of the non-living suspended matter were due to an appreciable admixture of dead diatom frustules. Fig. 3 also indicates that usually (and also in August) the median diameter is lower near the coast, higher offshore.

The same general pattern was found in autumn 1973 for the entire Southern Bight (Fig. 4a and b): along the coast, where river influence is highest, the non-living suspended matter is finer grained. It is also better sorted (Fig. 4c); skewness (Fig. 4d), however, shows a somewhat different pattern, as the largest skewness occurs in the southern half of the Southern Bight and along the Dutch coast and the lowest in the N-NW part of the Southern Bight.

Without further knowledge on the composition of the non-living fraction it is hazardous to explain these patterns. Probably the presence of near-shore sources of suspended matter (river, the Flemish Banks) influence the grainsize of the nearshore suspended material whereas offshore there may be a far greater preponderance of plankton debris.

Also the formation of aggregates may play an important role (KRANCK, 1973); and there probably is a mechanism of size selection.

In the August 1971 samples the median diameter was higher, the σ probably somewhat larger, and skewness somewhat less, coinciding with high amounts of plankton in the water. It follows that there is a possibility of error in determining grainsize: if in the plankton counts the amount of diatoms is underestimated with regard to the Coulter Counter results, the nonliving fraction will appear to be coarser than it actually is. Thus if during the JONSDAP cruises the offshore waters contained generally more plankton than the nearshore waters the observed distribution of Md, M and σ might reflect the plankton distribution and not any real differences in the non-living fraction. In order to test this the average Md and the range of values for Md were determined for all samples with a peak concentration of plankton in the fractions > 150 μ, 100 to 150 μ, 50 to 100 μ, 20 to 50 μ, 0 to 20 μ and with no or only small amount of plankton (Table II). If a positive relation is found

Table II

Median of non-living particles in samples with different size fractions of phytoplankton

Peak concentration of plankton in size fraction (μ)	Average Md of non-living fraction	Range of Md in non-living fraction
> 150	14.2	8.6-24.8
100-150	11.1	8.6-24.8
50-100	15.7	8.3-25.8
20-50	15.6	10.2-24.8
0.20	13.2	9.6-19.4
none	14.3	8.5-21.2

between Md and high amounts of plankton in the 20 to 50 μ and 50 to 100 μ fractions a higher Md may be the result of biased counting as well as of the admixture of plankton debris. Similarly a low Md in samples with a high amount of plankton in the 0 to 20 μ fraction may be due to biased counting. Table II, however, shows that there is no direct relation between the Md of the non-living fraction and the amount of plankton in the sample. We therefore assume the distributions as shown in Fig. 4 to reflect real differences in size distribution between near-shore (coastal) water and offshore (Channel) water.

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