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'Variations in zooplankton biomass as observed from the analysis of discrete water samples'

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Abstract:

Large volume water samples taken by a plankton pump (500 l) or by water bottles (30 l) in the Western Baltic during various seasons were analyzed for the plankton biomass expressed as organic matter and number of copepods in different size fractions. Examples for three types of variation are given: variations in double or replicate samples, small-scale vertical variation and meso-scale horizontal variation. The distribution pattern varies from fairly homogeneous (coefficient of variation 10 %) to strongly inhomogeneous (coefficient of variation 100 %). The range of variation sometimes exceeds an order of magnitude. The degree of variation is to some extent reflected in the vertical structure of the water masses (stratification). The mixed surface layer generally shows a smaller variation than the more stratified lower layers.

Introduction

As the connecting link between primary producers and fish, zooplankton plays a key role in pelagic food chain studies. It is thought that the availability of zooplankton as food for fish larvae is one fo the decisive factors determining the year class strength of commercial fish species (match - mismatch hypothesis,

CUSHING 1975). An important point in this context is the patchiness in zooplankton abundance. As STEELE (1976) points out 'the variance of plankton distribution, i.e. the maximum possible food concentrations, may be more important than the average'.
Since assessments of zooplankton stocks are usually made by means of vertically, obliquely or horizontally towed net hauls which necessarily yield only average values for the towed distance, data on small scale patchiness or the actual concentration of zooplankton are rare. So far, there are only two methods available for studying this problem. The first one relies on modern electronic equipment. Zooplankton concentration is measured by means of an electronic particle counter which may be either towed behind the ship (BOYD 1973) or operated on board in connection with a pumping system (MACKS 1976). The second one, more old-fashioned and laborious, consists in examining discrete water samples. Their volume should be large enough to permit a statistically valid estimation of at least the smaller zooplankton organisms up to the size of copepods. Another point, mostly neglected, is the inclusion of smaller forms such as nauplii and copepodits escaping the standard plankton nets with a mesh size of 300 µ or 500 µ.

The present study presents some data on the spatial distribution of zooplankton biomass and the number of copepods in different size categories, based on the analysis of large-volume water samples.

Material and Methods

Two series of large-volume water samples were taken in the Kiel Bight and Kiel Fjord in the Western Baltic (Fig. 1) and size-fractionated by means of filter units with different mesh sizes immediately after hauling.

Tab. 1: Summarized sampling data

Date	Stations	Area	Sampling depth
A. Aug.70 - July 71	No.7-20	Kiel Bight (Great Belt)	0.2-28 m (10-35 m)
B. April 76 - June 76	No.A-D	Kiel Fjord	1 and 5 m

Gear	Sample volume	Size fractions (µ)
A. Plankton pump (LENZ 1972)	500 l	150-300, 300-600, >600
B. Hydrobios-Rosette Sampler with 30 l Niskin bottles	30 l	100-300, 300-2000

In survey A, station numbers are identical with cruise numbers. During some of the monthly cruises, several days were spent at anchor, thus enabling 2 to 3 sample series to be taken on successive days. In survey B, station numbers indicate fixed positions (A, B, C, D) visited fortnightly, in all 5 times.

The size-fractionated plankton samples were filtered through pre-weighed ash-free paper filters (Schleicher & Schüll, 598/1) for dry weight determination and subsequently combusted at 550° C. The difference between the dry weight and the ash weight, corrected for carbonate losses by HCl-titration, is taken as the content of organic matter in the sample.

Before combustion, the dried filters were examined for copepods which are detectable by their red colour. The counting procedure under a low magnification lens was faciliated by a counting grid of plexiglass put over the filter. An exact enumeration is not possible when high concentrations of very small copepods (nauplii and copepodits) clump together and then the filter is covered by a layer of phytoplankton, as was sometimes the case.

Results

For convenience's sake, both surveys will be first treated separately on account of the differences in methodology and in the sampling scheme. In survey A 500 l-samples were taken by a plankton pump during an annual cycle, while in survey B we used 30 l-water bottle samples obtained from a fixed sampling area consisting of 4 stations a quarter of a nautical mile apart (Fig. 1).

Seasonal cycle (Survey A)

Fig. 2 - 5 gives an impression of the seasonal cycle studied for particulate organic matter and the number of copepods in different size fractions. In accordance with the thermohaline stratification of the water masses, a characteristic feature of our area during most of the year, the data are presented separately for the mixed surface layer ($\Delta t < 1^{\circ}C$, $\Delta S < 1^{\circ}/oo$) and for the varyingly stratified lowerlayers. The number of samples per station and layer varies between 1 and 6, the average being 3 to 4. The depth intervals between two successive samples usually varied between 2 and 5 meters. The bars indicate the range of variation. The occasional large variation, especially in copepod numbers (Fig. 4 and 5), causes considerable fluctuations in the annual curve.

It should be mentioned that the content of organic matter can only rarely be taken as the biomass of the corresponding number of copepods, since other zooplankters such as ctenophores for instance, which are numerous during wintertime, as well as larger phytoplankton cells and diatom chains contribute to the organic matter. The influence of phytoplankton is generally restricted to the smaller size fractions.

Variation in depth distribution (Survey A)

To enable a better comparison of the variation observed in the content of organic matter and the amount of copepods in both layers, the coefficient of variation was chosen. Tab. 2 summarizes the statistical distribution of the coefficients calculated for each size group and sample series. With the exception of organic matter in the surface layer, the variation tends to increase with size fraction, pointing to a more patchy distribution of larger organisms. This finding sounds reasonable, though it may be affected by the sample volume which is probably more representative of the smaller than the larger size fractions. This is evident in the number of copepods, where large specimens were completely missed during November and December.

The second finding, the increase in variation in the lower layers compared with the upper can be explained by the hydrographic structure in our area. The lower layers are frequently stratified, since here we have superimposed water masses of different origin. In the largest size group (>600 μ), the difference in variation between both layers is significant at the 1 % probability level for organic matter as well copepod numbers.

At several stations, replicate samples were taken from the same depth (Tab. 3). Remarkable are the samples at St. 19, which in contrast to the others were separated by a time interval of 7 hours and show the lowest variation. In general, there is no significant difference in variation as compared with Tab. 2.

Horizontal variation (Survey B)

Fig. 6 and 7 show the horizontal variation observed between the 4 fixed stations A - D in the interior of the Kiel Fjord (Fig. 1). Both sampling depths, 1 and 5 m, are taken together because of negligible stratification down to the 5 m depth. At the two last sampling dates, a heavy phytoplankton bloom (mainly Skeletonema costatum) made counting of copepods in the smaller size fraction impossible. Although the general horizontal distribution is found to be fairly uniform over the observed distance of 1 mile, there are some instances of patchiness causing a strong change in concentration, especially in copepod numbers.

With the rosette sampler, it was possible to take double samples in 30 l-bottles, arranged about 30 cm apart, the aim being to obtain an impression of small-scale variation. In Tab. 4 the coefficient of variation in these double samples is compared with that between the 4 stations of the sampling area. The content of organic matter does not show much difference between both types of variation. As is to be expected, the degree of variation over the whole sampling area is higher in most cases, but usually only slightly. Where the opposite is found, it is obviously the effect of a greater number of samples falling into the same size range. In copepod numbers however, there is a clear difference in variation between double samples and sampling area, indicating a higher patchiness than found in organic matter. The latter parameter naturally has a more integrating character because of its various components. If we regard only copepods alone, we may find the same biomass values for 10 large or 1000 small individuals because of their size differences. In any case, general biomass parameters such as particulate organic matter are not expected to vary as much as the number of individual organisms.

A problem, not really solved here, is the influence of methodological errors on the observed sample variation. 20 weighed-in samples of organic matter showed a precision (coefficient of variation) of 4.4 %. The precision in counting copepods was not tested. It is estimated to lie in the range of 10 %.

Summary

1. The depth variation observed within the mixed surface layer through the analysis of 500 l-samples compares well with the meso-scale horizontal variation found in 30 l-samples. The coefficient of variation averages between 30 to 35 % for the content of organic matter and between 45 to 65 % for the number of copepods per water volume.

2. Exceptions with a much stronger variation (coefficient of variation over 100 %, range of variation up to an order of magnitude) are by no means rare, especially in summer.

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3. The larger variation in the lower layers is apparently due to their hydrographic structure, featuring frequently observed multiple stratification.
4. Replicate and double samples do not show a significantly smaller variation than found for depth or horizontal distributions.

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Tab.2 Depth distribution (St. 7 - 20): Statistical distribution of the coefficient of variation (x)

Size fractions	Mixed surface layer 150-300 µ	Mixed surface layer 300-600 µ	Mixed surface layer > 600 µ	Lower layers 150-300 µ	Lower layers 300-600 µ	Lower layers > 600 µ
A. Copepods/m^3						
Sample series (n)	17	17	12	15	17	11
Mean value ($\bar{x}$)	45.25	46.65	52.00	53.46	65.72	94.54
Standard deviation (s)	29.98	34.05	26.01	33.62	38.46	43.12
Coeffic. of variation (v)	66.25	72.99	50.01	62.88	58.52	45.61
Range (x_{min}-x_{max})	12.9-115.1	8.7-141.4	5.5-103.4	1.1-136.6	7.5-126.9	15.5-172.7
B. Organic matter/m^3						
Sample series (n)	17	17	17	17	17	17
Mean value ($\bar{x}$)	34.88	32.87	28.11	38.60	45.96	52.42
Standard deviation (s)	19.63	14.10	22.46	16.28	28.13	23.75
Coeffic. of variation (v)	56.27	42.89	79.90	42.17	61.20	45.30
Range (x_{min}-x_{max})	8.0-91.8	10.6-65.6	3.2-92.6	17.8-62.6	8.3-104.8	26.0-114.4

Tab. 3 Replicate samples (Survey A = St. 7 - 20): Coefficient of variation with number of samples (n)

St.No.	Depth (m)	n	Organic matter/m^3 150-300 µ	Organic matter/m^3 300-600 µ	Organic matter/m^3 >600 µ	Copepods/m^3 150-300 µ	Copepods/m^3 300-600 µ	Copepods/m^3 >600 µ
11	35	6	12.8	23.9	-	59.3	23.1	-
16	3	2	44.6	67.1	37.6	27.1	70.7	69.2
17	1	4	44.4	26.0	43.3	-	32.2	167.5
19	26	2	35.0	3.7	8.5	13.9	2.7	11.8
Average			34.2	30.1	29.8	33.4	32.1	82.8

Tab. 4 Horizontal distribution (St. A - D): Coefficient of variation for double samples (DS) and whole sampling area (SA)

Date	Organic matter/m^3 100 - 300 µ DS	Organic matter/m^3 100 - 300 µ SA	Organic matter/m^3 300 - 2000 µ DS	Organic matter/m^3 300 - 2000 µ SA	Copepods/m^3 100 - 300 µ DS	Copepods/m^3 100 - 300 µ SA	Copepods/m^3 300 - 2000 µ DS	Copepods/m^3 300 - 2000 µ SA
12.4.76	31.7	26.1	28.4	32.7	32.9	53.7	25.1	56.8
26.4.76	13.1	16.7	45.1	47.8	67.2	78.7	30.1	67.3
10.5.76	29.7	36.2	28.7	30.8	13.2	67.5	26.3	60.0
24.5.76	30.5	37.3	28.6	19.4	-	-	42.2	81.8
3.6.76	23.2	34.4	37.0	34.6	-	-	52.3	66.2
Average	25.6	30.1	33.5	33.0	37.7	66.6	35.2	66.4

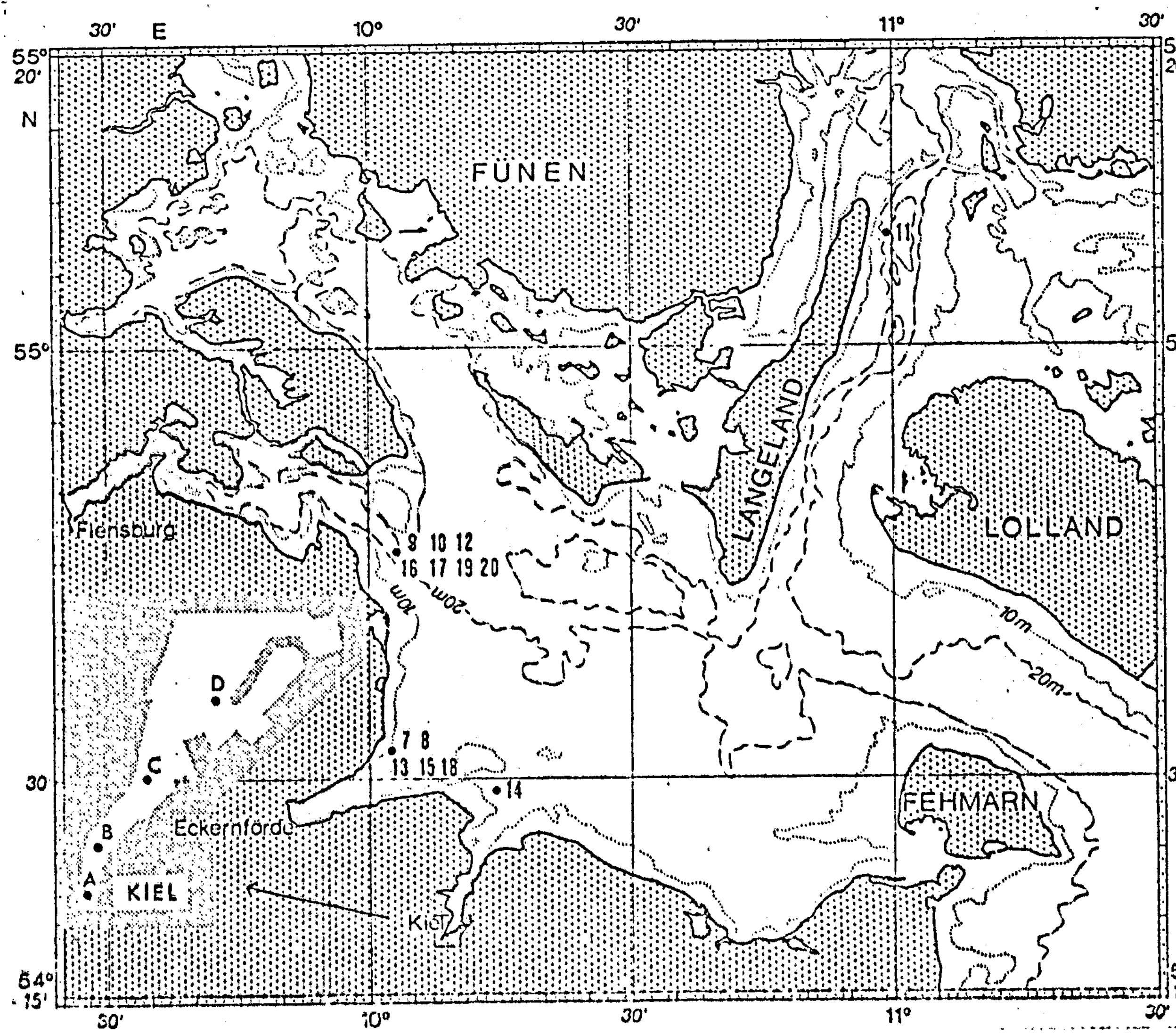
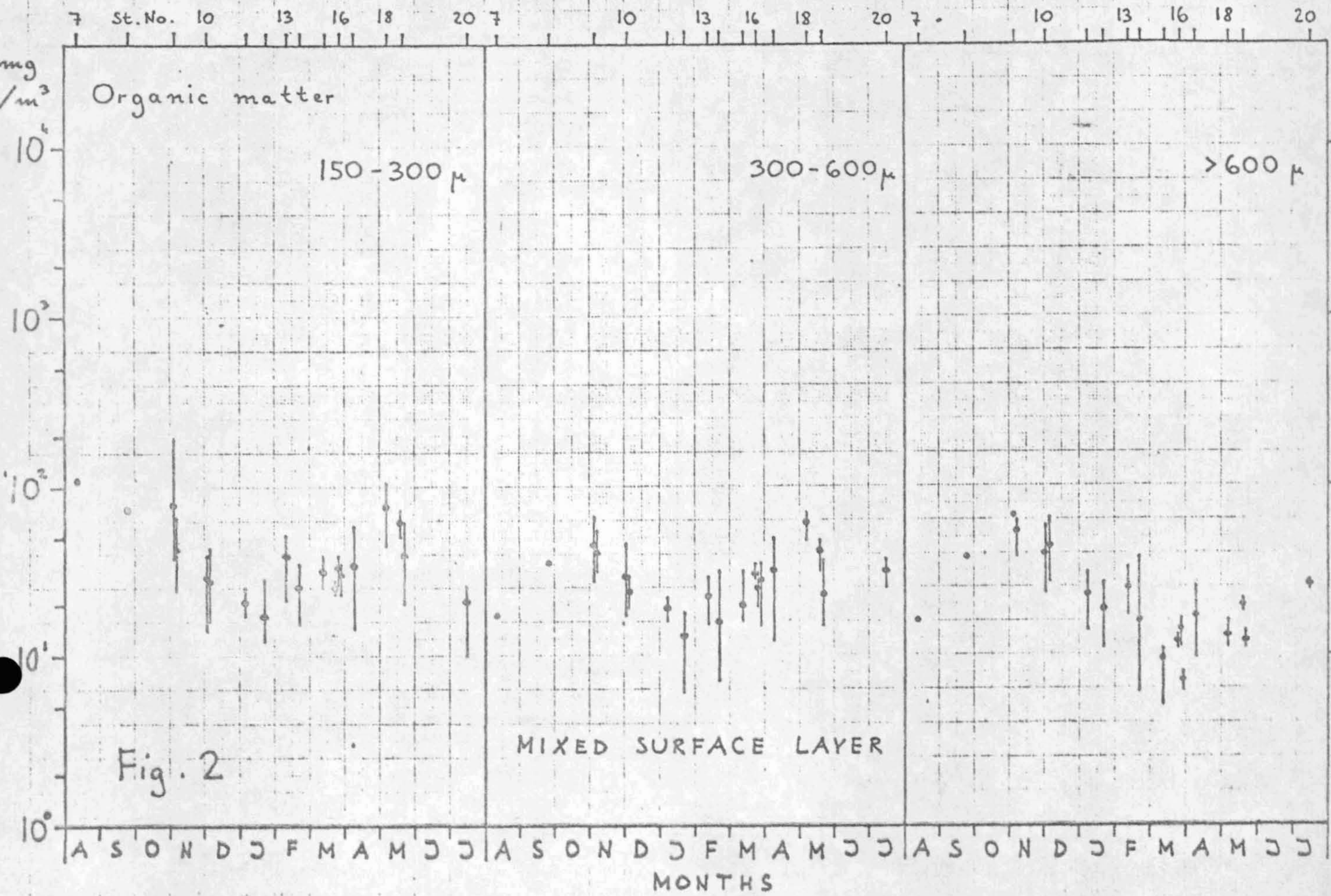
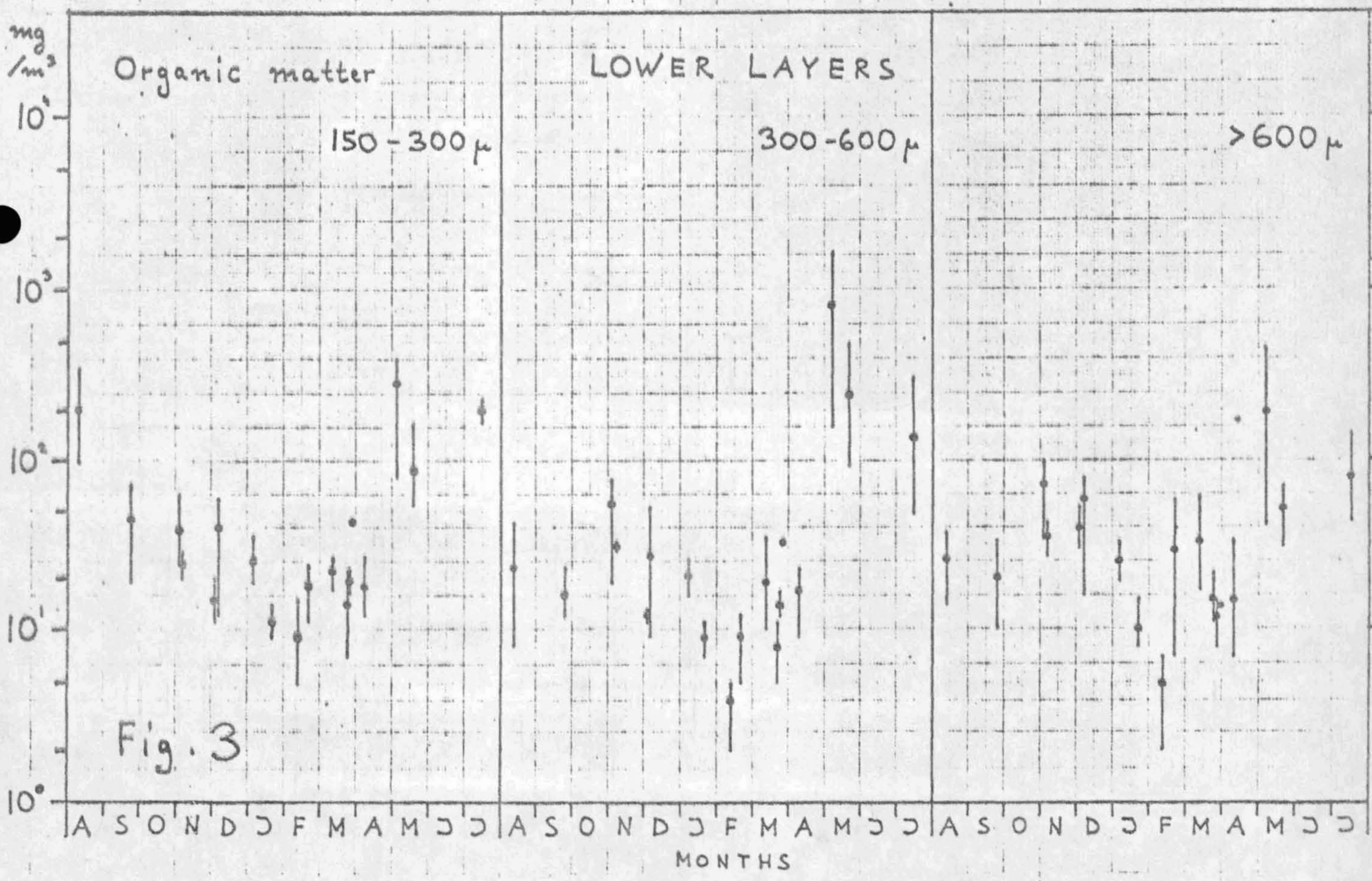


Fig. 1 Position of sampling stations



St. No.
7
10
13
16
18
20
mg/m³
Organic matter
150-300 μ
300-600 μ
>600 μ
MIXED SURFACE LAYER
10^0
10^1
10^2
10^3
10^4
A S O N D J F M A M J J
MONTHS

Fig. 2



mg/m³
Organic matter
LOWER LAYERS
150-300 μ
300-600 μ
>600 μ
10^0
10^1
10^2
10^3
10^4
A S O N D J F M A M J J
MONTHS

Fig. 3

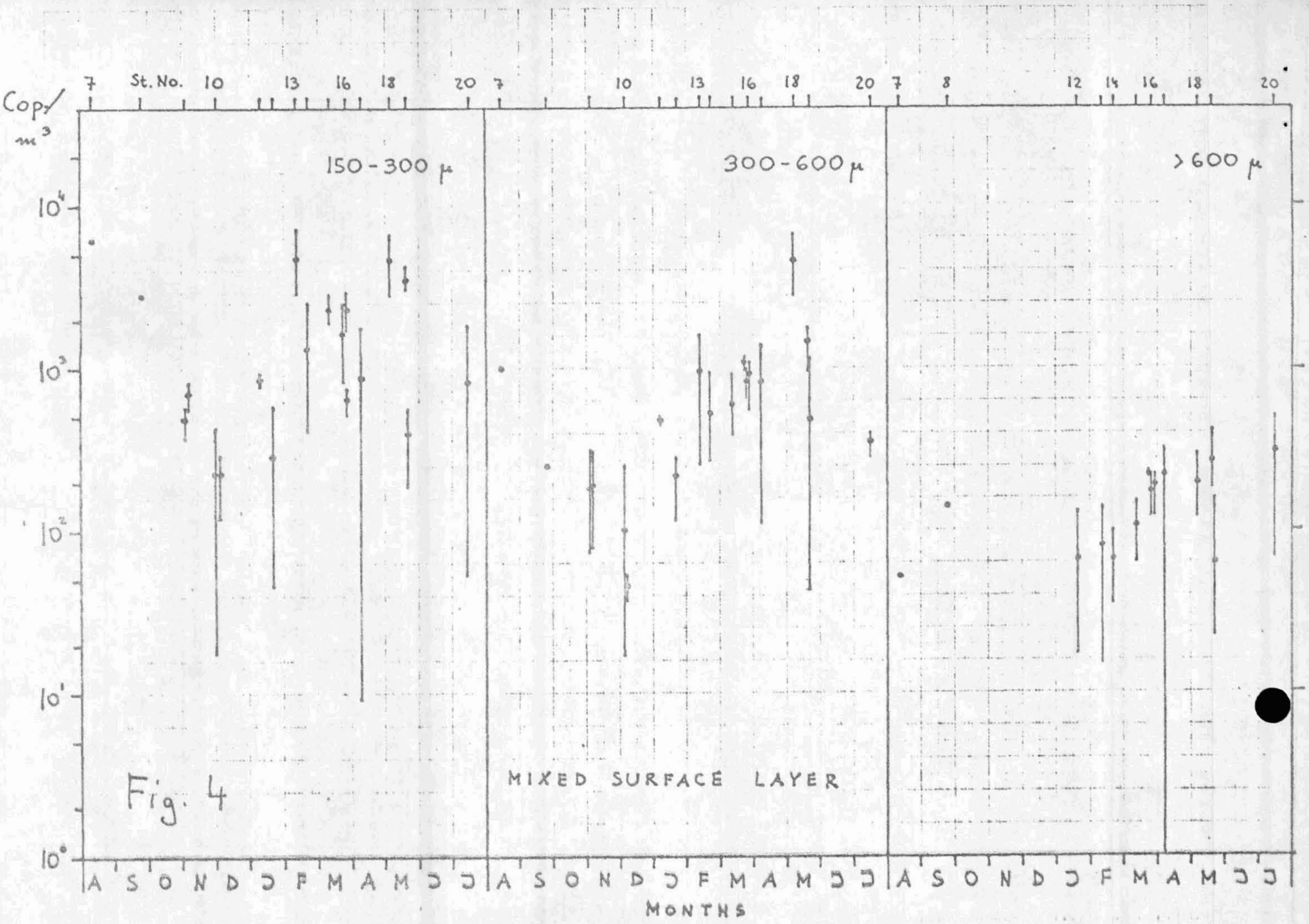

St. No.
7 10 13 16 18 20
7 10 13 16 18 20
7 8 12 14 16 18 20
Cop./m³
10⁴
10³
10²
10¹
10⁰
150-300 μ
300-600 μ
>600 μ
MIXED SURFACE LAYER
A S O N D J F M A M J J
MONTHS

Fig. 4

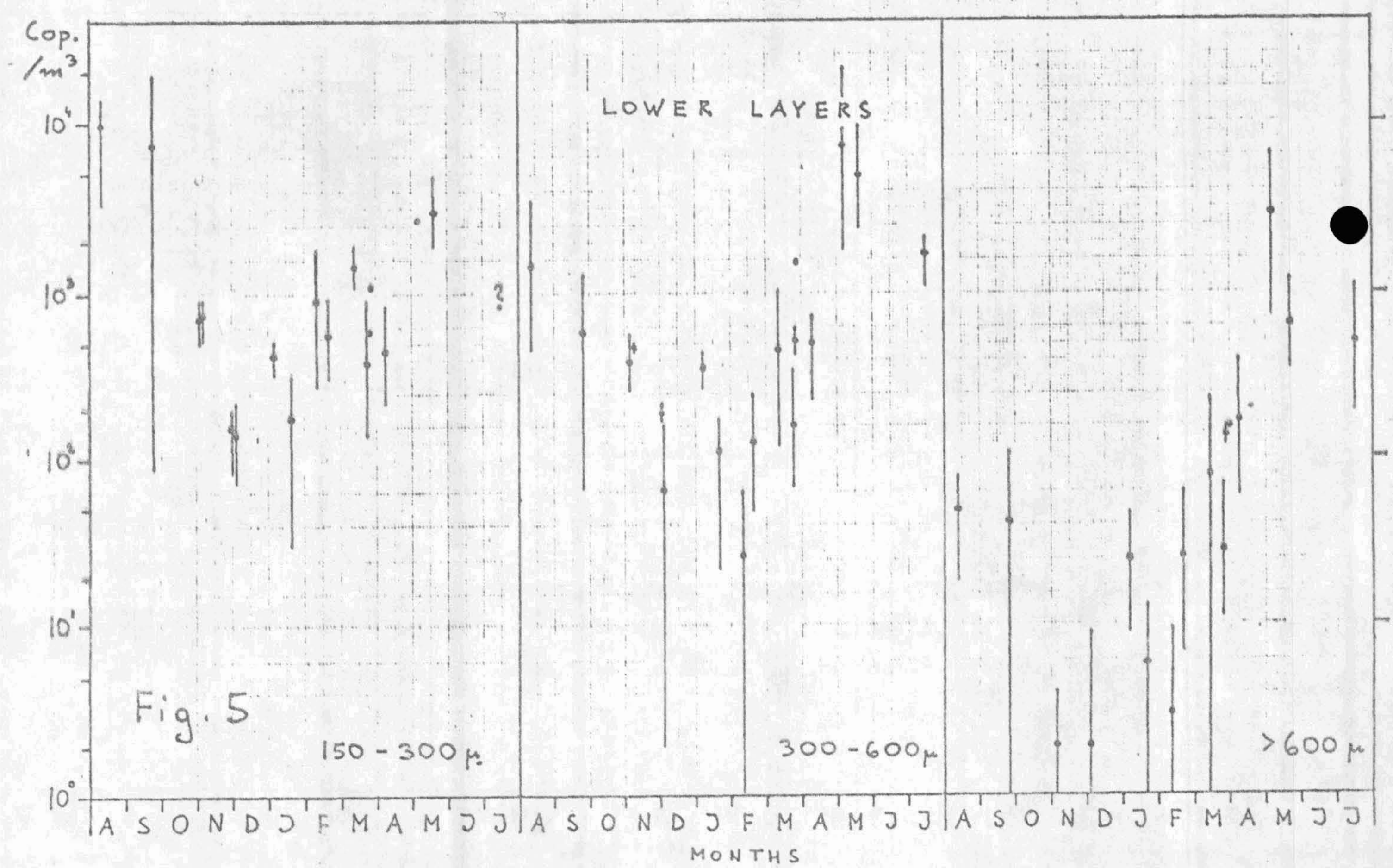
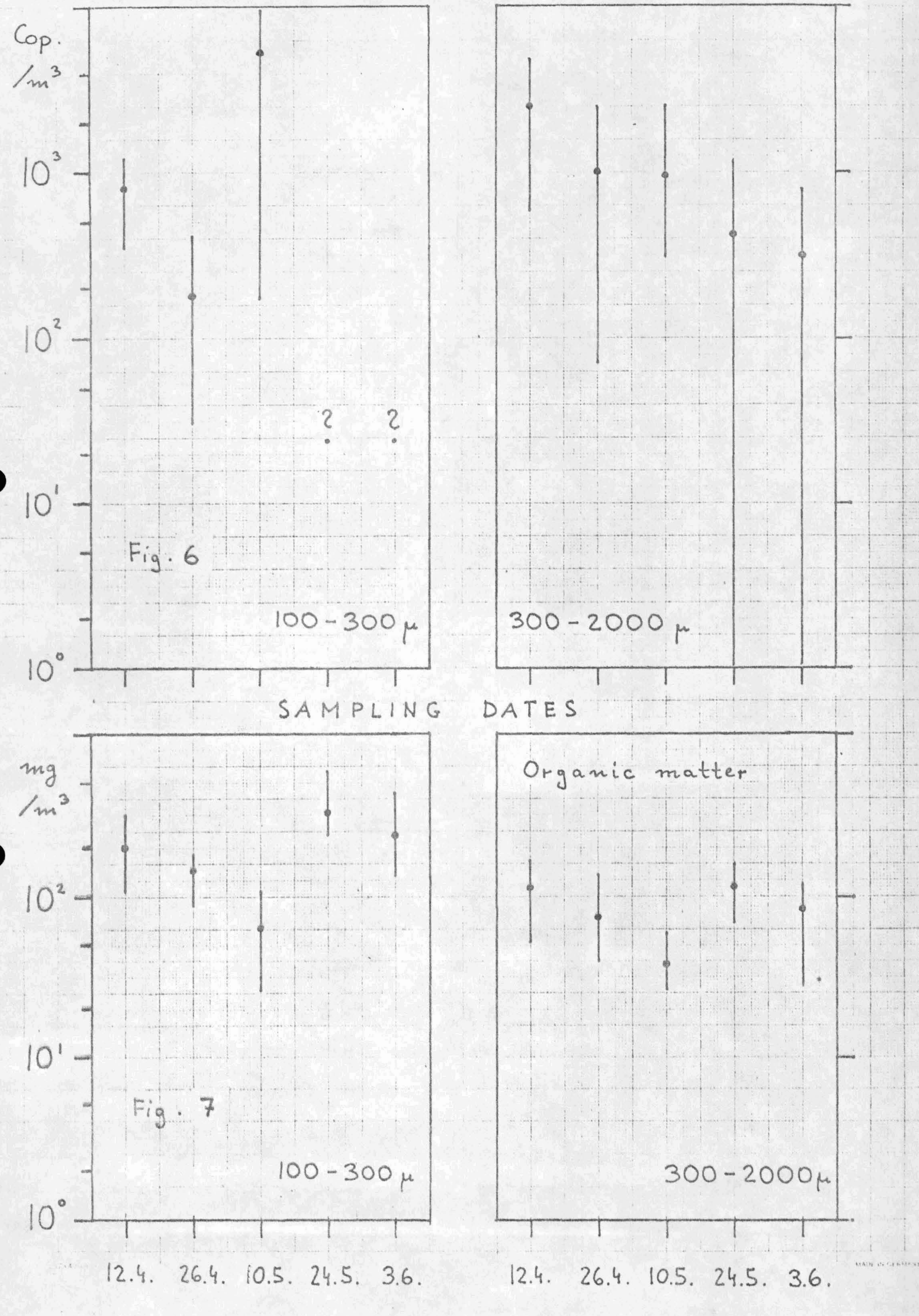

Cop./m³
10⁴
10³
10²
10¹
10⁰
LOWER LAYERS
150-300 μ
300-600 μ
>600 μ
A S O N D J F M A M J J
MONTHS

Fig. 5



Cop. /m³
10³
10²
10¹
10⁰
Fig. 6
100 - 300 μ
300 - 2000 μ
? ?
SAMPLING DATES
mg /m³
10²
10¹
10⁰
Organic matter
Fig. 7
100 - 300 μ
300 - 2000 μ
12.4. 26.4. 10.5. 24.5. 3.6.
12.4. 26.4. 10.5. 24.5. 3.6.