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On primary production in the Baltic

by

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Introduction

During the summer of 1961 a few C_{14} measurements according to Steemann Nielsen (1958) was carried out in the Bothnian Sea. In November the same year such measurements were started at Finngrundet lightship in the same sea. The series of measurement are continuing but between March and June this year there was a break. The measurements until March are presented below.

Measurements of conventional hydrography including PO_4-P is carried out by all the states around the Baltic many times a year. Below is presented computations of primary production (p.p.) from the phosphate data according to a method by Steele (1956).

On many of the Swedish expeditions also daylight has been determined in five wave lenghts. Some results are presented.

Some earlier determinations of primary production in the Baltic.

The following values of p.p. are taken from Kalle (1949). They are estimations from phytoplancton investigations. The values are given in g C/m^2 and month and are for the Gulf of Finland 1.5, for the western Baltic 3 and (for comparison) the English Channel 7.5.

In an article 1954 Buch computed the plant production for a station in the northern Baltic proper during the time 20/4 - 26/5 1941 in three different ways from the changes of ΣCO_2, O_2 and PO_4-P. The mean value was 11 g C/m^2 and month, For the summer of 1945 the same method gave a p.p. of 18 g C/m^2 and month. Buch did however not take the vertical transport into consideration. Concerning the Gulf of Bothnia Buch (1945) writes: "Because the excess CO_2 (for definition see Buch /1945/) in the deeper parts of the Gulf of Bothnia is about 1/3 of what is found in the deepest part of the Baltic proper it might be reasonable to assume that the organic substance which is to be oxidized also stands in the same proportion."

Fishing is much less in Baltic than in e.g. the North Sea. According to Dietrich and Kalle (1957) the former was of the amount 2.4 kg/ha 1948, while the latter was 27 kg/ha. Just for the orientation of the order of magnitude the following distribution of the 2.4 kg/ha has been computed as if the ratios of the Swedish fishing catches of 1958 were the real ratios: Western Baltic proper 8 kg/ha, the rest of the Baltic proper 2 kg/ha and the Gulf of Bothnia 0.5 kg/ha.

Primary production according to the PO_4-method.

Without using mathematics the method of Steele (1956) may be described in the following way. It is assumed that in the p.p. PO_4-P is taken up in a constant proportion to the produced carbon. Therefor during the time between two measurements, PO_4 is decreasing. At the same time, however, PO_4 is transported from above or below (out or in) due to vertical turbulent transport. This transport is equal to the product of the vertical gradient of PO_4 and a factor, the "Austausch" coefficient. This coefficient is assumed to be equal for PO_4 and temperature and is therefore determined from data of temperature. The decrease of PO_4 + the inflow of PO_4 is equivalent to the p.p.. Horizontal transport is not taken into account.

The amounts of PO_4-P in the surface waters of the Baltic are lowerthan for the ocean, see Fig. 1 which presents mean values (only Swedish measurements) of the surface mixed layer for different times of the year and different parts of the Baltic. Especially small are the amounts in the Bothnian Sea. We have so far no measurements of our accuracy of these low concentrations but Table 1 showing the mean values and the standard deviations of 5 measurements during 24 hours on an anchor station in the Bothnian Sea gives a piece of information about the accuracy.

Swedish, Russian and once Finnish data have been used for the computation of the p.p. between 0 and 20 m, (under the assumtion of no regeneration in this layer). As the ratio C:P has been used the figure 60 (pr weight) partly because Buch (1954) used it with a reference to Harvey (1950) (determinations on diatoms made by Ketchum and Redfield), partly because Buch (1945) got about this figure in a rough calculation from data of the excess of ΣCO_2 and PO_4. Steele (1956) used however the factor 41 according to Sverdrup et/al. (1946). The results of the calculations are presented in Figs 2 and 3, the latter from the west coast of Sweden for comparison. Because most of the measurements are not closer in time than two months, so far the possibility in few cases of using smaller time intervals has not been taken.

The following mean values of p.p. have been deduced from the Figures 2 and 3

The Gullmar Fjord (Alsbäck)	March-July 1960-1961	12.7 g C/m^2 and month	
The Bornholm Deep	February-October 1959	7.5	"
The Gotland Deep	" " 1958-59	2.1	"
The Landsort Deep	" " "	1.3	"
The Bothnian Sea 23/7 -7/11 1958			
	mean value of 6 stations	0.75	"
"	June 1956 (8 days)	14.0	"

The last figure is one of those high ones often met with when the time interval is very small. The influence of the length of the interval has to be further studied. The use of the same factor C:P all over may not be correct. We know e.g. from Fonselius (1961) that there is much more PO_4 then is expected from the O_2-values when the conditions are stagnant in the deepest parts of the Gotland Deep. This effect must contribute to the high values of the ratio regeneration to p.p. (See Table 2). But even regeneration computations from oxygen data give higher values than the p.p. So far only a few such computations has been made; viz. for the Christiansö Deep during 1952 (Naut. Met. Annual Copenhagen) and for the Gotland Deep during small intervals of the years 1953-56. The "Austausch" coefficient was this time computed from salinity instead of temperature. The result was 6 g C per m^2 and month at the Gotland Deep, 15 g at the Bornholm Deep and in the Gullmar Fjord 12 g C/m^2 and month or nearly the same as the p.p. above. One of the possible reasons for these higher values might be the fact that the current system is such that at both the Baltic stations water is passing which comes from areas with higher production. - The varying values of the Austausch coefficient used in the PO_4-method above is clear from Table 3.

C 14 - Measurements.

All the measurements of the C 14 has been made according to Steemann Nielsens (1958) in situ method during one half day. The ampoules have been delivered by the Central Agency of C 14 determination at Charlottenlund Slot. The beta-radiation of the filters have been counted at the same place. Concerning the measurements on Finngrundet carbon dioxide has been computed from Buch's (1945) formula :

$$\Sigma CO_2 = 0.19 + 0.34 \times Cl \quad \text{mmol/L}$$

but for the two stations F32 and MS 7 pH and alkalinity was determined. The p.p. has been computed from the formula :

$$1.1 \times \text{counts/min f.sample} \times \Sigma CO_2 \text{ mmol} \times 2 \times 12 \times 10^3 \; / \text{ counts pr min. for ampoule} = \text{mg } C/m^2 \text{ and day.}$$

The factor 1.1 is according to Steemann Nielsen (1958). Special experiments have to be done to examine how good this factor is for the Bothnian Sea. The result of the measurements is presented in Fig. 4 Here are also Danish mean values for the Kattegatt according to Steemann Nielsen (1958 b)

It is at once clear that the C-14 results are much higher than would be expected according to the PO_4-method from the computation. It is however preferable to wait for more measurements both of C-14 and PO_4 before the discrepancy is discussed.

Light measurements

Light measurements in five length have been carried out in May and November 1959, August 1960 and July 1961. The following filters (Schott and Genossen) have been used: RG1, RG5, RG8, VG9, BG12+GG5 and BG12 + UG1. Directly or indirectly values of light intensity is derived for rather narrow bands around the wave lengths 375 mμ (ultraviolett) 465 m μ (blue), 535m (green), 630 and 680m (red). Values of the transmission per m for a surface layer 5-10 m is presented in Fig. 5. No regard has been paid to values of the surface since it is hard to measure this value. To the left in Fig. 5 measurements in July-August show the different curves for different parts of the Baltic, with the clearest water in the south and the most turbid in the north. The difference is biggest in the shorter wave lengths due to yellow substance. In the figure is also presented the curve belonging to coastal water No 4 according to Jerlov and Kullenberg (1946). According to personal communication with Dr. Jerlov, who has a lot of new measurements in the Gullmar Fjord this curve has to be in the higher wave lengths. Fig. 5, middle and right show variations with the time of the year. In spite of the fact that the light has to travel a longer path in November than during May and July-August the highest values of transmission is met with then. The values of May ought to be checked because at that time a combination of Speedomax and high outer resistance was used to give a non - linear connection between reading and intensity.

Conclusions

Measurements of C-14 -p.p. and light intensity and computions of p.p. with the aid of PO_4-values have been presented. The earlier opinion that the p.p. decreases towards the inner parts of the Baltic is again confirmed by the PO_4 method. How large the decrease is however is not clear because of uncertainty in the choise of the factor C:P and the big length of the time interval. It is also not quite clear if the C-14 p.p. and the PO_4-p.p. have to give the same result.The C-14 p.p. measurements are too few to allow to conclusions. For the future continued measurements of especially C-14-p.p. and if possible PO_4 are planned on Finngrundet. When the picture clears the light intensity data will be used for the computation of light energies in attemts to explain the different primary production.

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Anonymous

Data from the Fishery Board of Sweden ICES punch card index except for the Gullmar Fjord.

USSR, State Oceanographic Institute (IGY World Data Center A.)

Naut. Met. Annual. Copenhagen.

Table 1

24 hour anchor station Bothnian Sea July 58

Depth	PO_4-P		T^0C	
m	Mg-at/L			
	M.V.	St. dev.	M.V.	St. dev.
0	0.06		11.90	
10	0.04	± 0.03	11.70	± 0.12
20	0.07	± 0.02	9.94	± 0.85
30	0.08	± 0.03	4.92	± 0.39
40	0.07	± 0.03	3.04	± 0.07
50	0.08	± 0.01	2.83	± 0.04
60	0.06	± 0,03	2.70	± 0.02
70	0.06	± 0.03	2.26	± 0.19
80	0.15	± 0.06	1.81	± 0.10

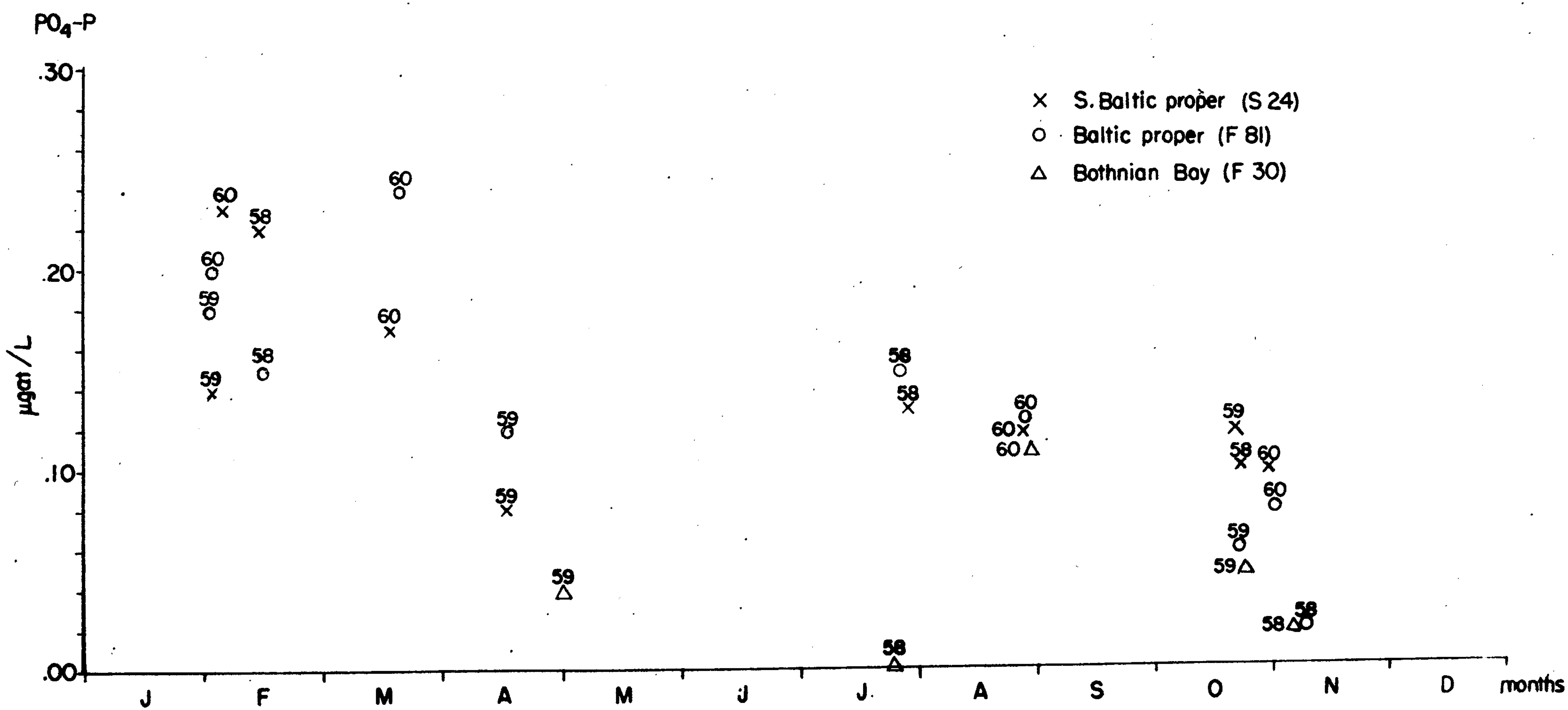
Table 2

	Regeneration to p.p. (20m-bottom)
Alsbäck	1.6
The Bornholm Deep	4.1
The Gotland Deep	18.0
The Landsort Deep	100.0
The Bothnian Sea	3.6

Table 3

"Austausch 2 coefficient cm^2/sec

Depth m	Alsbäck 20/6-26/7 1960	Bornholm Deep 10/8-18/10 1959	Gotland Deep 25/7-10/8 1958	Landsort Deep 11/8-28/10 1958
0				
10	0.118			
20	0.217	0.190	0.118	0.038
30	0.185		0.710	
40	0.077	0.272	0.001	
50	0.036			0.009
60	0.068	0.168	0.242	
70	0.780		0.045	0.032
80	(0)		0.019	
90				
100			0.150	0.068
150				0.425
200			0.087	2.120
400				2.170



PO_4-P
μgat/L
.30
.20
.10
.00
S. Baltic proper (S 24)
Baltic proper (F 81)
Bothnian Bay (F 30)
J
F
M
A
M
J
J
A
S
O
N
D
months

Fig. 1

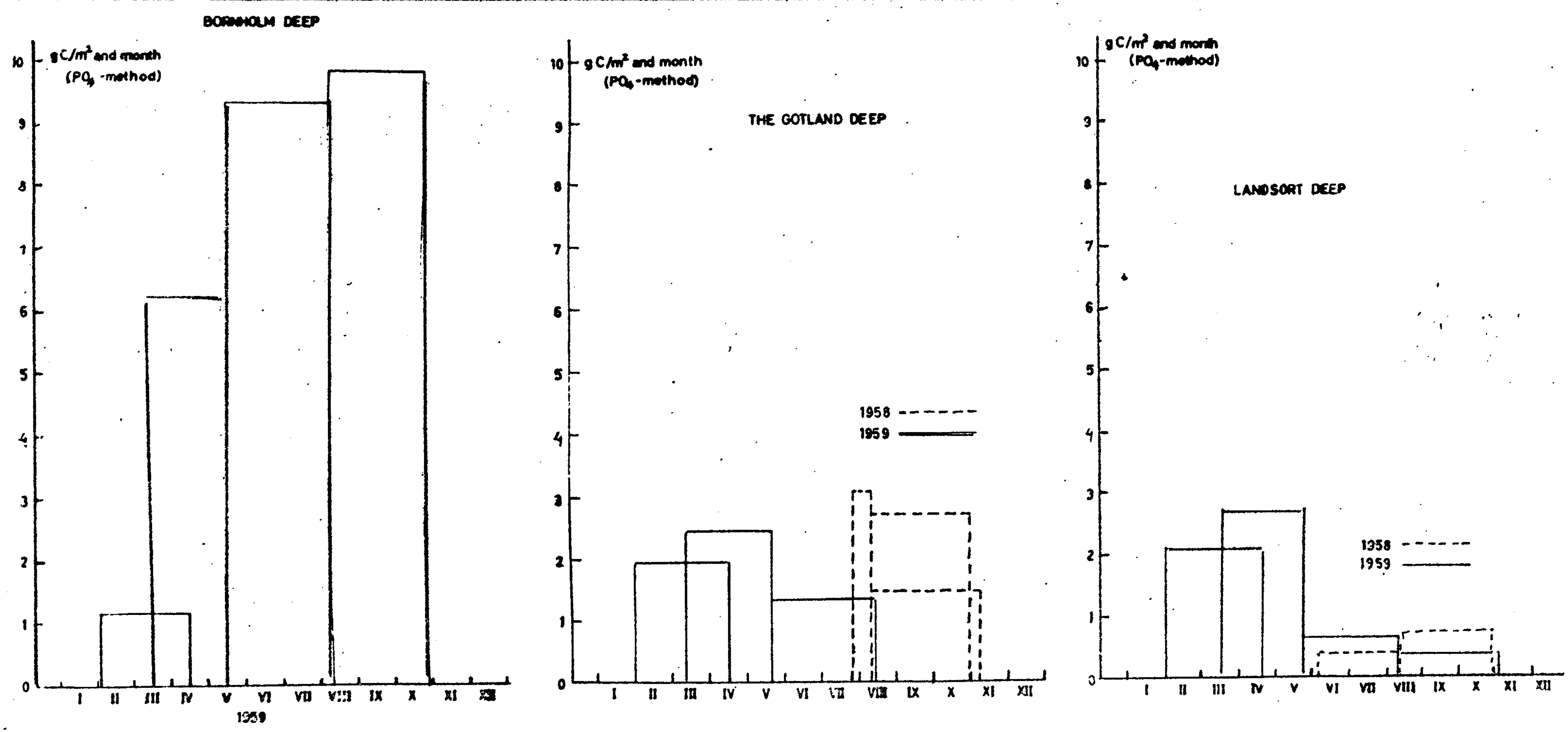
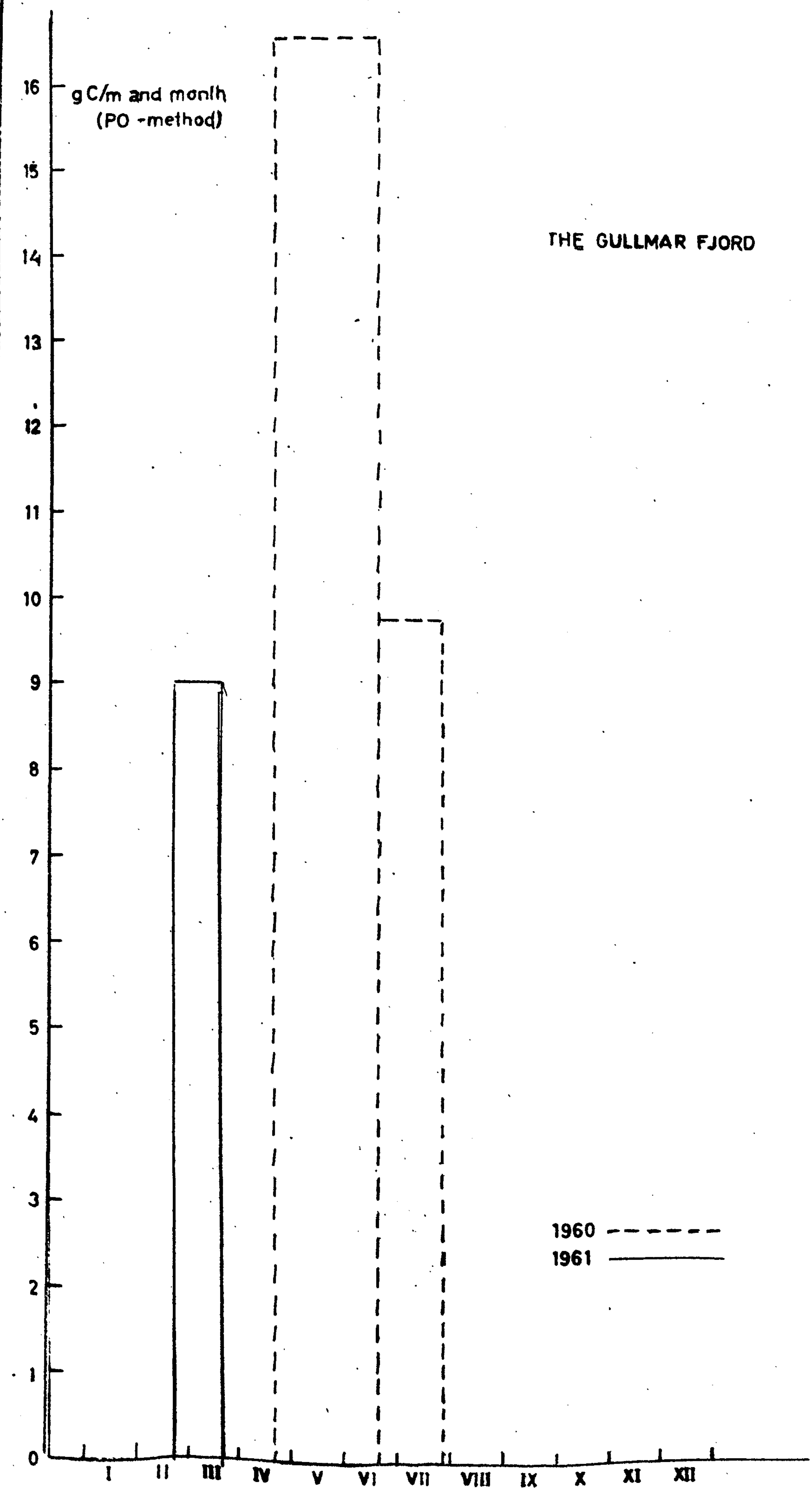
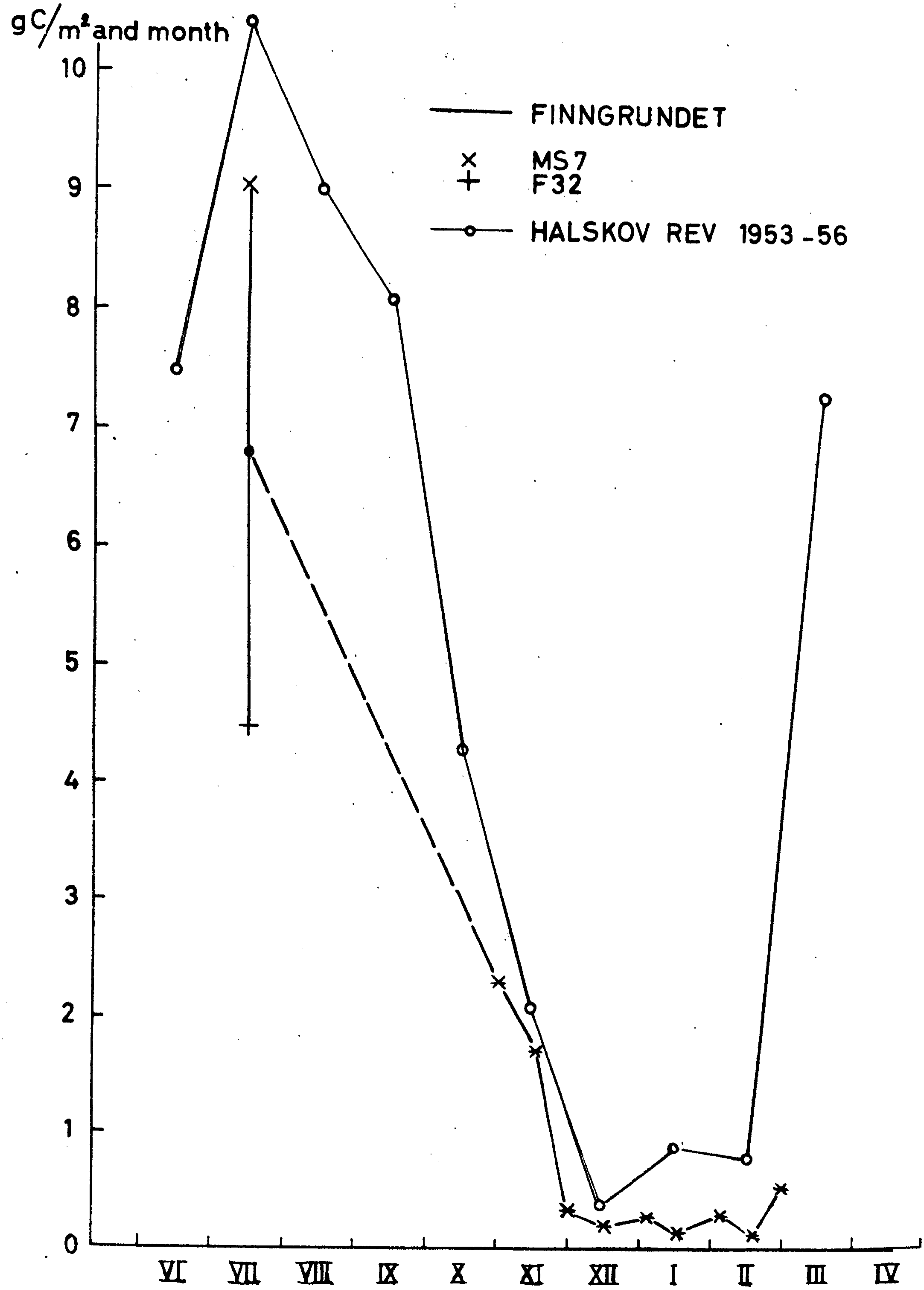
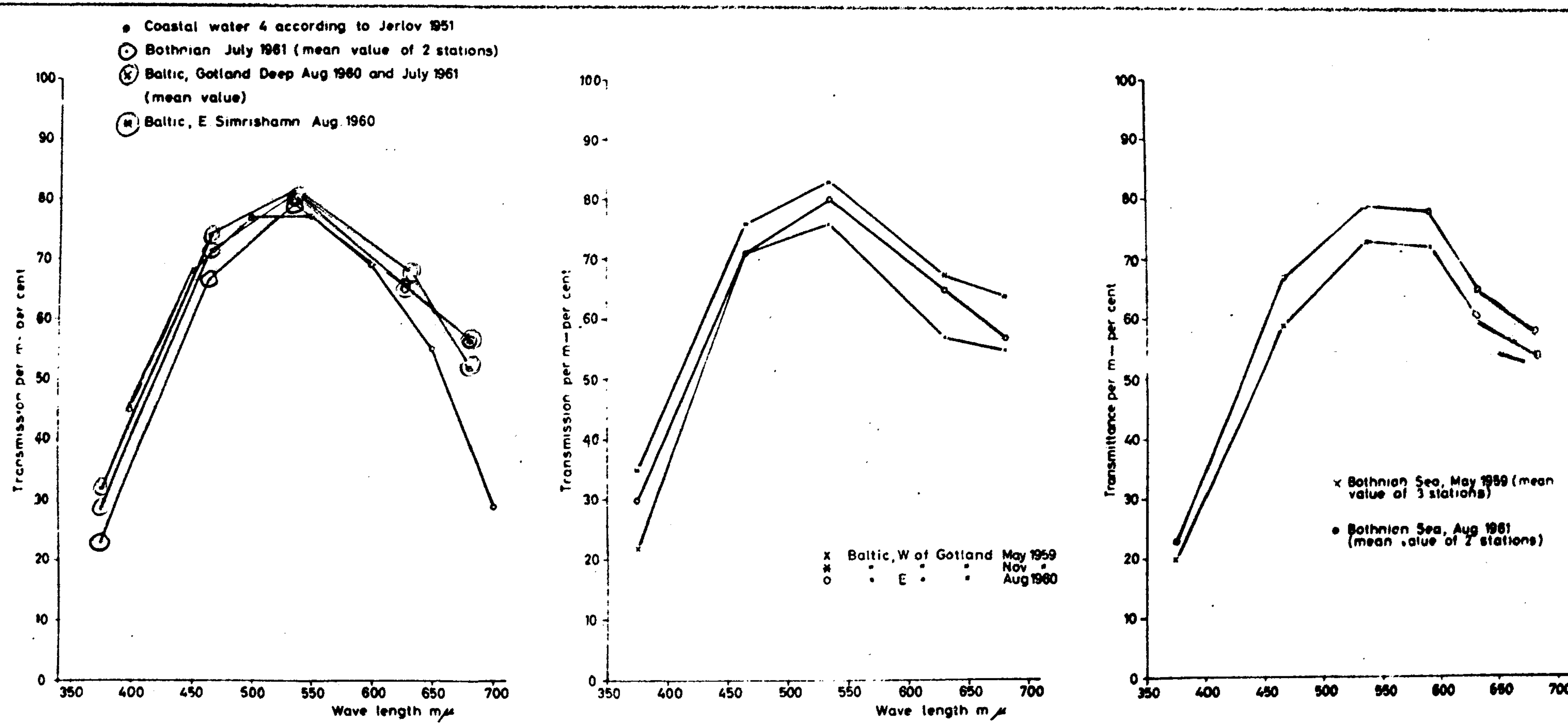

BORNHOLM DEEP
g C/m² and month
(PO₄ -method)
10
9
8
7
6
5
4
3
2
1
0
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
XII
1959
g C/m² and month
(PO₄-method)
THE GOTLAND DEEP
1958
1959
LANDSORT DEEP
1958
1959

Fig. 2

Fig. 3


THE GULLMAR FJORD
g C/m and month
(PO -method)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
XII
1960
1961


gC/m² and month
10
9
8
7
6
5
4
3
2
1
0
FINNGRUNDET
MS7
F32
HALSKOV REV 1953-56
VI
VII
VIII
IX
X
XI
XII
I
II
III
IV
1961
1962



Coastal water 4 according to Jerlov 1951
Bothnian July 1961 (mean value of 2 stations)
Baltic, Gotland Deep Aug 1960 and July 1961 (mean value)
Baltic, E Simrishamn Aug. 1960
Transmission per m - per cent
Wave length mμ
Transmission per m — per cent
Baltic, W of Gotland May 1959
Nov
E
Aug 1960
Wave length mμ
Transmittance per m — per cent
Bothnian Sea, May 1959 (mean value of 3 stations)
Bothnian Sea, Aug 1961 (mean value of 2 stations)

Fig. 5