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PLANCTONIC HETEROTROPHIC BACTERIA: NUMBERS AND ACTIVITY - 1974.

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1. Numbers

The annual cycle of the planctonic heterotrophic bacteria counts shows a succession of three peaks in april, june and october 1974 (figure 1) - But it must be known that those high results are due only to one counting each time, the other ones beeing at a much lower level. It is clearly necessary to have more samples taken at these periods - For the same reason, we did not separate our results within the three classical zones, feeling the number of samples was too low. It can be said that the obtained curves show the same kind of spatial distribution already found in 1973 (Joiris, 1973 ; Podamo, 1973)

In table I the mean values of number of marine heterotrophic bacteria are shown (calculated on the basis of surface samples, assuming that the water column is homogenous).

TABLE I : Numbers of marine heterotrophic bacteria (mean values) 1974

zone	n	numbers of bacteria bact/ml	bact/m^2
IS	35	24,1 10^3	3,6 10^{11}
IN	9	38,5 10^3	7,7 10^{11}
II	25	1,8 10^3	5,5 10^{10}

2. Activity

a) Initial rate of consumption of oxygen

The total respiration rate of fresh sea-water was utilized as a measure of the activity of heterotrophic aerobic bacteria. The asumption that the respiration rates of zooplancton and phytoplancton are to be neglected, is confirmed by the results obtained in view of measuring the activity of these organisms (Heyden *et al*. : 1973/ BIOL 1, 2 and 3).

The initial rate of oxygen consumption is plotted in figure 2. For the same kind of reasons as for the countings, we use only the mean value per cruise ; the obtained curves are very similar for the three zones.

It can be seen, when comparing the figures 1 and 2, that there exists a good correspondance between numbers of bacteria and initial consumption rates of oxygen (peaks in april, may-june and october). This gives a confirmation that the oxygen consumption rate is correlated with bacteria and, indeed, represents mainly bacterial activity.

b) Annual mean of bacterial activity

In order to quantify the flux of energy going through the compartment "heterotrophic activity" in the North Sea, we expressed the measured activity in G C/m^2 year, on the basis that :

- there is an equimolar relationship between oxygen and carbon fluxes.
- the water column is homogenous, so that, the values obtained with surface samples were extrapolated (see table II).

TABLE II : Initial consumption rate of oxygen (mean values) 1974

zone	n	rate of consumption (μ M O_2/h)	heterotrophic activity (G C/m^2 y)
IS	24	0,92	1 449
IN	13	1,41	2 961
II	22	1,41	4 441

c) Dark fixation of $^{14}CO_2$

It is possible to attribute most of the dark fixation of radioactive bicarbonate to bacterial activity (see discussion in the reports of the phytoplancton group). On this basis, considering this dark fixation to be an anaplerotic one, it is possible to quantify the bacterial activity - The first results show an activity comparable (at least same order of magnitude) with the results of the oxygen method.

d) Another, indirect, method can be used in order to evaluate the bacterial activity : from the respiration rate given for various bacteria in the litterature (Giese, 1962), we found back results of the same order of magnitude for the bacterial populations in the North Sea.

e) Discussion

This first attempt to quantify the heterotrophic activity in North Sea water needs some comments. The obtained results, coming from both the oxygen consumption rate and the dark bicarbonate fixation, seem too high : they are at least one order of magnitude higher than the net primary production. Because phytoplancton is considered as the main source of organic matter in the sea, and thus the support for heterotrophic activity,it seems impossible for this activity to be higher than the phytolancton production.

It is interesting to note that other results of bacterial activities (Sorokin, 1973) are also considered to be to high to represent real in situ activities (Banse, 1974)

In our case, some hypotheses could explain that the results are abnomally high :

1° It is known that bacteria are actively growing when water is put in a glass bottle. In our case, the determination of activity is done within some hours, and we did control that the bacteria are not growing significantely the first 10 hours. Howkever, it remains possible that their activity is affected much more quickly than their growth, and that we are measuring activities higher than the real in situ ones.

The first experiments made in order to test this hypothesis indicate that the volume of the bottles is not important for the oxygen consumption : the wall-effect of the bottles on the bacterial activity might not disturb this activity during the first hours.

2° As a simplification, we considered the water column as beeing homogenous for the heterotrophic activity, and have extrapolated the values from surface samples to the whole water column. But this part of organic matter actively released by the phytoplancton is probably not uniformely released in the water column, and must follow the depth distribution of primary production in the euphotic zone (Fogg, 1963). So, it is quite possible that the measured activity of surface water is not to be extrapolated to the whole water column, as we did until now.

This second hypotheses will be tested during the 1975 sampling cruises, by making measurements of oxygen consumption at different depths.

3. Organic matter

The concentration of the substrate for the heterotrophic activity : the biodegradable organic matter, was measured with the classical BOD_5 method.

The annual evolution of BOD shows an important peak in summer period (april-june 1973, possibly april-september 1974) and a smaller peak in winter period (november-january) (see figure 3). Such results are in good agreement with other ones from the litterature (Morris and Foster, 1971).

The spatial distribution of the BOD does not reflect any clear coast-effect : this indicates that most of the concerned organic matter is not of exogenous origin. (see table III) The main source for organic material could indeed be the primary production, for instance.

TABLE III : Organic matter : annual mean - 1974

zone	n	BOD (μ M O_2)	Organic Content (g C/m^2)
IS	22	120,5	21,7
IN	11	149,5	35,9
II	23	112,1	40,4

A first test was made in january 1975 in order to look for an eventual vertical distribution of the BOD (point M 20). It seems that such a distribution exists in the water column, even with a very low winter primary production : the BOD was 86 at the surface, 30 at 16 m and 32 at 33 m depth.

Proportion between organic matter and phytoplanctonic biomass. The results of organic material concentration (see table III) can be compared with the phytoplanctonic biomass calculated from the chlorophyll data (see Podamo, 1973) : table IV.

TABLE IV : Mean values of organic matter and phytoplancton biomass in the North Sea (g C/m^2).

zone	Organic matter	Phytoplancton
IS	22	0.3
IN	36	0.4
II	40	0.1

The proportions are in good agreement with the accepted distribution of the organic matter in the sea (Parsons, 1963) :

soluble organic	100
particulate organic	10
phytoplancton	2
zooplancton	0,2
fish	0,002

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Legends to the figures :

Fig. 1 Annual cycle of the planctonic heterotrophic bacteria in the Southern Bight of the North Sea (countings) - 1974.
Each point is the mean of a numbers of samples, indicated in the graph near the plotted value.

Fig. 2 Annual cycle of the planctonic heterotrophic activity in the Southern Bight of the North Sea (initial oxygen consumption rate) 1974
The number of samples corresponding to each point is indicated in the graph near the plotted value.

Fig. 3 Annual cycle of the organic matter in the Southern Bight of the North Sea (BOD_5) (see fig. 2)

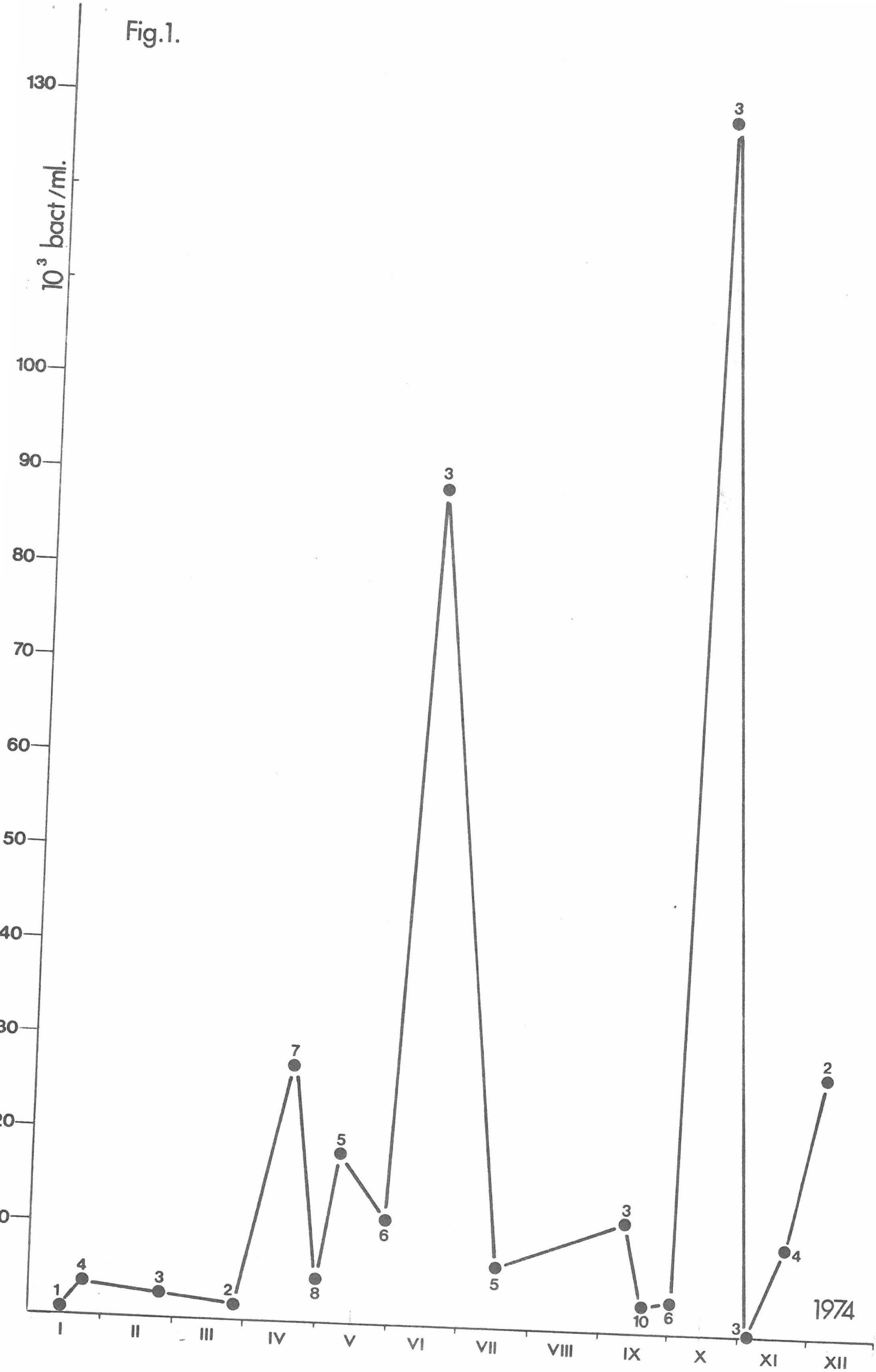
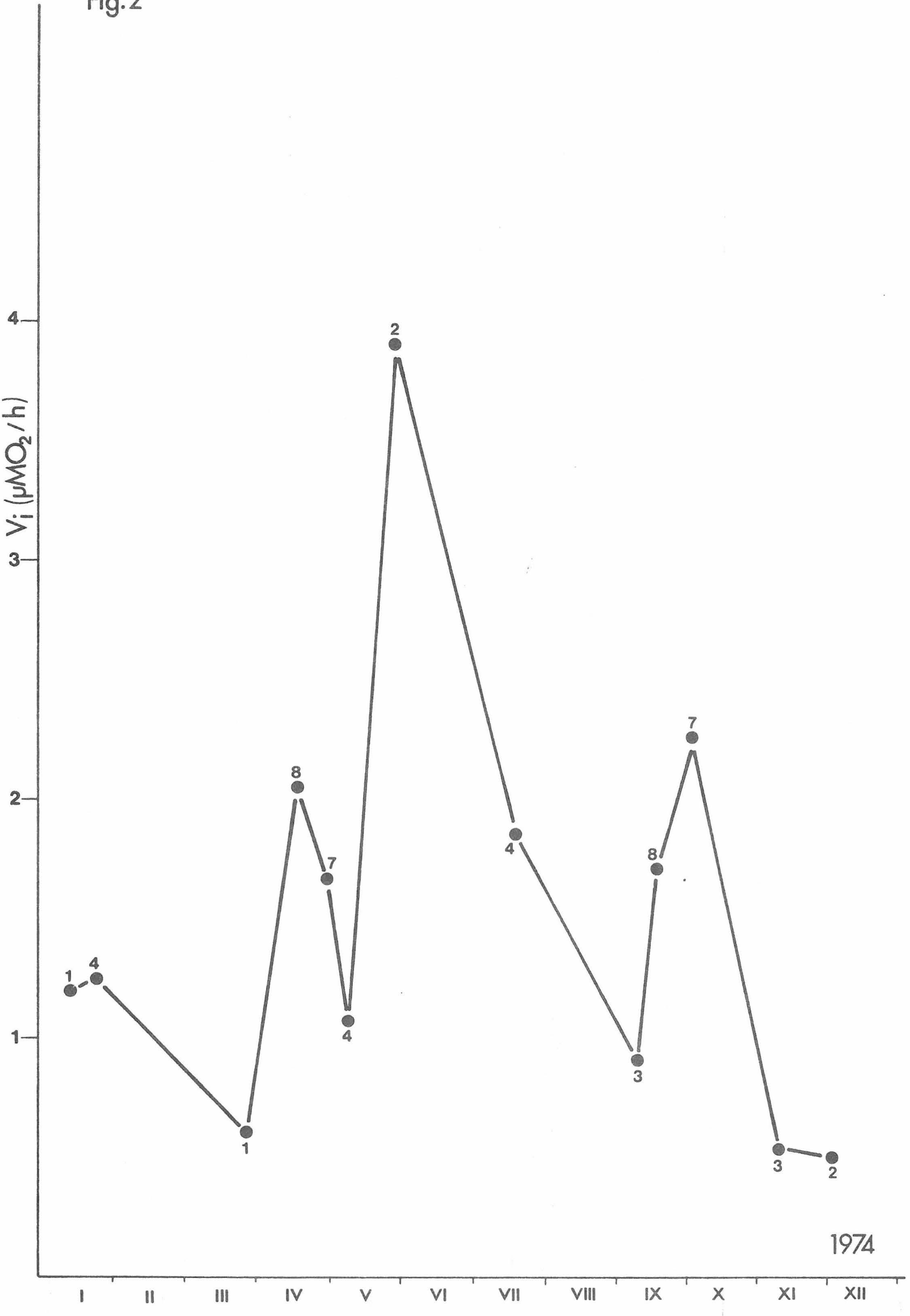


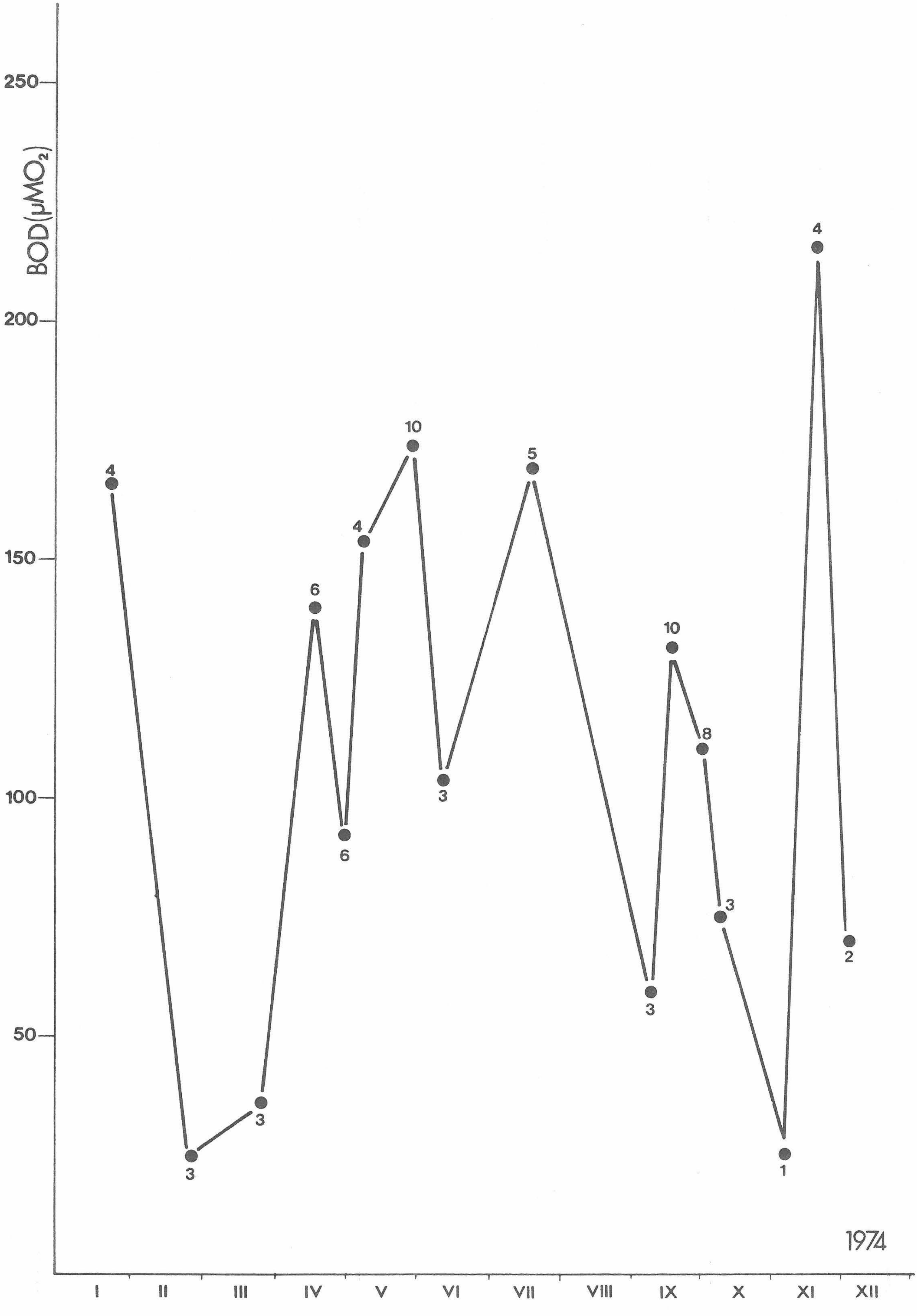
Fig.1.
130
100
90
80
70
60
50
40
30
20
10
10³ bact./ml.
1974
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
XII

Fig. 2



Vi (μMO2 / h)
4
3
2
1
2
8
7
4
1
4
1
4
7
8
3
3
2
1974
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
XII

Fig. 3.



BOD(μMO2)
250
200
150
100
50
4
3
3
6
6
4
10
3
5
3
10
8
3
1
4
2
1974
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
XII

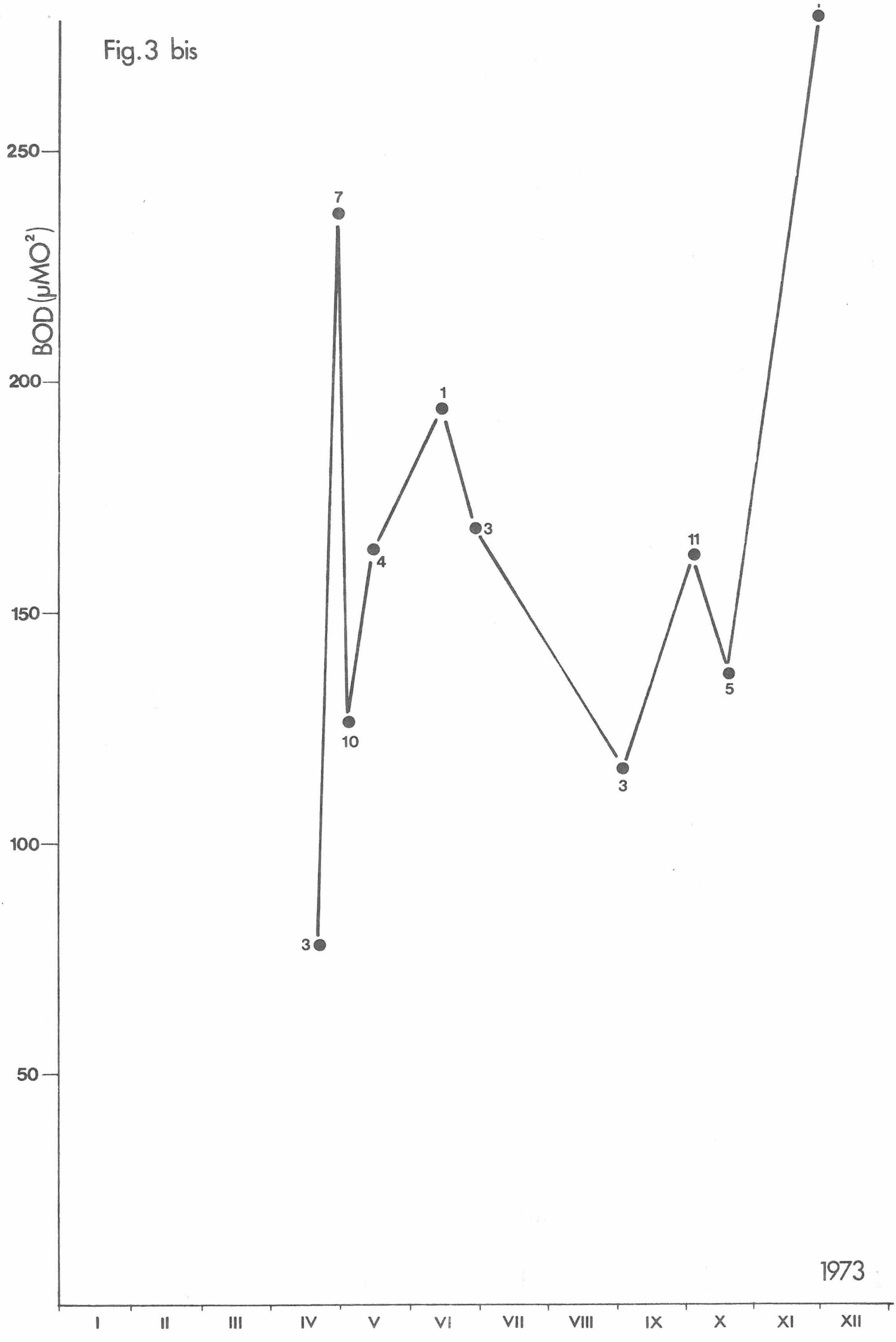


Fig. 3 bis
BOD (μMO²)
250
200
150
100
50
7
1
3
4
11
10
5
3
3
1973
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
XII

Annex I : Basic results North Sea 1974

Date (1974)	Station	Zone	Mar. bact. (10^3/ml)	Initial O_2 consumption ($\mu M\ O_2$/h)	BOD_5 ($\mu M\ O_2$)
14-1	55	IZ	0,94	1,2	≥306
23-01	01	IZ	12	1	220
23-01	09	2	1	0,9	107
24-01	20	2	0,41	1,2	141
24-01	16	1N	0,36	2,0	194
25-2	55	1Z	1,57		26
26-2	01	1Z	3,77		31
26-2	09	2	2,03		19
25-3	55	1Z		0,6	18
26-3	01	1Z	2,60	3	77
26-3	09	2	0,38		13
19-4	01	1Z	3,60	1,7	99
17-4	55	1Z	0,64	2,7	≥286
19-4	02	1Z	8,00	1	118
18-4	16	1N	174	1,9	178
17-4	09	2	0,69	5	175
16-4	20	2	0,74	2,5	188
19-4	04	2	16,0	0,4	54

Date (1974)	Station	Zone	Mar. bact. (10^3/ml)	Initial O_2 consumption (μ M O_2/h)	BOD_5 (μ M O_2)
29-4	01	1Z	21,0	0,9	32
30-4	55	1Z	0,96	0	$\geq$250
1-5	16	1N	4,85		92
2-5	22	1N	3,45	0	
30-4	09	2	0,67		51
1-5	20	2	0,67	7,4	169
2-5	25	2	2,38	5,7	58
3-5	15	2	0,65	0	149
10-5	01	1Z	78,0	0	
7-5	55	1Z	5,95	8,6	249
9-5	16	1N	2,56	1,6	179
7-5	09	2	3,18	1,3	128
9-5	20	2	0,28	1,4	59
17-5	09	2	0,69		
27-5	01	1Z	54,0	3,7	$\geq$265
27-5	02	1Z	2,70	3,9	160
29-5	05	1Z	8,00	3	139
27-5	04	2	0,46		150
28-5	20	2	1,33	0,9	200
28-5	25	2	0,84	2,3	
11-6	01	1Z	57,0		153
12-6	16	1N	207,0		89
12-6	20	2	1,92		68
30-5	12	1Z		4,8	148
29-5	55	1Z		3,2	191

Date (1974)	Station	Zone	Mar. bact. (10^3/ml)	Initial O_2 consumption (μ M O_2/h)	BOD_5 (μ M O_2)
29-5	09	2		3,9	142
29-5	15	2			$>$286
30-5	21	1N		2,4	210
30-5	16	1N		10	202
30-5	17	1N		8,4	216
30-5	11	1N			$>$401

Date (1974)	Station	Zone	Mar. bact. (10^3/ml)	Initial O_2 consumption (μ M O_2/h)	BOD_5 (μ M O_2)
16-7	01	1Z	27,0	2,4	132
17-7	55	1Z	0,98	0,2	158
18-7	16	1N	2,04		212
18-7	20	2	0,31		228
19-7	09	2	1,86		116
9-9	01	1Z	23,0	1,4	91
10-9	55	1Z	1,79	0,8	39
10-9	09	2	10,0	0,5	45
18-9	17	1N	0,62	3	81
18-9	16	1N	15,0	0	124
17-9	01	1Z	0,99	2,3	148
17-9	02	1Z	0,53		114
19-9	05	1Z	6,0	3	119
19-9	55	1Z	1	0,4	137
18-9	18	2	1,73	1,2	169
18-9	20	2	1,25		183
18-9	19	2			
19-9	08	2	1	2,8	109
19-9	09	2	0,7	2,2	129

Date (1974)	Station	Zone	Mar. bact. (10^3/ml)	Initial O_2 consumption (μ M O_2/h)	BOD_5 (μ M O_2)
3-10	07	1Z	16,0	3,8	149
30-9	04	1Z	0,3		57
1-10	25	2	0,22	0	65
1-10	24	2	1,09	1,4	125
1-10	23	2	0,25	2,2	135
1-10	22	1N	2,0	2,4	71
1-10	21	1N		2,3	68
1-10	16	1N		3,7	179
10-10	09	2	2,62		74
7-10	01	1Z	337		6
9-10	55	1Z	48		145
22-10	01	1Z			159
4-11	01	1Z	0,5	0,6	
5-11	55	1Z	0,26	0	
6-11	09	2	0,032	1,6	25
18-11	01	1Z	5,1		160
20-11	02	1Z	1,48		193
18-11	55	1Z	22		205
21-11	20	2	0,15		304
04-12	01	1Z	26	2,4	110
4-12	16	1N	29	0,5	50

ANNEX 2 : Mean values per cruise : 1974

Period	zone	Parameter Mar. bacteria	Initial consumption	BOD
23-24.01	IS	12	1	220
	IN	0,36	2	194
	II	0,70	1,05	124
	mean	3,44	1,26	165,5
25-26.02	IS	2,67		28,5
	II	2,03		19
	mean	2,46		25,3
25-26.03	IS	2,6	0,6	47,5
	II	0,38		13
	mean	1,49	0,6	36
16-19.04	IS	6,12	1,8	108,5
	IN	93	1,55	174
	II	5,8	3,96	139
	mean	27	2,05	140,2
29.04-03.05	IS	10,98	0,45	32
	IN	4,15	0	92
	II	1,29	3,7	106,7
	mean	4,43	1,66	91,8
7-10.05	IS	41,98	0	249
	IN	2,56	1,6	179
	II	1,73	1,35	93,5
	mean	17,99	1,07	153,7
27-30.05	IS	21,57	3,7	159,8
	IN	-	5,27	195,5
	II	0,88	2,82	164,2
	mean	11,22	3,92	174
11-12.06	IS	57		153
	IN	207		89,5
	II	1,92		68,5
	mean	88,64		103,6

Period	zone	Parameter Mar. bacteria	Initial consumption	BOD
16-19.07	IS	13,99	1,3	145,4
	IN	2,04	-	212
	II	1,09	2,4	172,4
	mean	6,44	1,85	169,5
9-10.09	IS	12,40	1,1	65,5
	II	10	0,5	45,8
	mean	11,60	0,9	58,9
17-19.09	IS	2,13	1,5	129,9
	IN	7,81	1,5	102,9
	II	1,17	2,06	148,1
	mean	2,88	1,71	131,8
30.09-03.10	IS	8,15	3,8	145,6
	IN	2	2,8	106,4
	II	0,52	1,2	96
	mean	3,31	2,25	110,5
7-10.10	IS	192,5		76,1
	II	2,62		74
	mean	129,2		75,4
4-6.11	IS	0,38	0	
	II	0,03	1,6	25
	mean	0,26	0,53	25
18-21.11	IS	9,52		186
	II	0,15		304
	mean	9,57		215,5
04.12	IS	26	2,4	110
	IN	29	0,5	50
	mean	27,5	0,75	80