NRA ANGLIAN 252

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NRA

National Rivers Authority
Anglian Region

AN ECOLOGICAL STUDY OF THE EFFECTS OF FERRIC DOSING ON THE PLANKTON AND BENTHIC INVERTEBRATES OF GRAFHAM WATER BETWEEN MAY 1990 AND NOVEMBER 1991.

FINAL REPORT

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ENVIRONMENT AGENCY
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CONTENTS

1 INTRODUCTION

Since July 1990, ferric sulphate dosing of Grafham Water Reservoir has been carried out by Anglian Water as part of a strategy to lower phosphate levels and thereby reduce the incidence of blue-green algae blooms. In 1990 dosing was carried out by a combination of methods - discharge from the draw off tower, discharge from the aeration tower and from a barge. In 1991 dosing was carried out almost entirely from the aeration tower. Substantial quantities of ferric sulphate have been used. During 1991, up to 2,500 tonnes per month were being discharged, with a total of around 25,000 tonnes for the year up to September 1991. The ferric sulphate being in an 11% solution as iron. The National Rivers Authority has carried out biological monitoring over this time to assess any effects of the dosing programme on the plankton and on the benthic invertebrates of the reservoir.

2 SAMPLING PROGRAMME

2.1 Figure 1 shows the sampling sites used at Grafham Water. Samples were taken at seven sites for plankton and at nine for benthic invertebrates.

2.2 Plankton samples were taken weekly, from the 23 May to the 25 November; a total of 28 surveys. Benthic samples were taken each month from May to November; a total of 7 surveys.

2.3 Phytoplankton numbers were assessed by taking water samples, fixing with Lugol's iodine and carrying out counts on sedimented sub-samples.

2.4 The zooplankton was quantified by filtering a known volume of water through a zooplankton sieve, preserving the sample with formalin and taking counts from sub-samples.

2.5 Benthic invertebrates were collected by sampling the substrata with an Ekman grab sampler of 0·0225m² surface area. The samples were preserved with formalin. Between May and September, 2 replicates were taken at sites 2, 3, 4, 5, 6, 7, 8 and 9. In October and November, 3 replicates were taken at sites 2, 5, 6, 7, 8, 9, 14, 15 and 16.

3 RESULTS AND OBSERVATIONS

3.1 Chemical Parameters - Total Phosphate

Great reductions in total phosphate have been achieved in 1991 compared to 1990. See Figure 2. June 1990 = approximately 1 mg/l, May-June 1991 = approximately 0.1 mg/l. The latter level was sustained throughout most of May to November. At around this level, phosphate is believed to be limiting to blue green algae.

3.2 Phytoplankton

A wide variety of phytoplankton taxa were present in Grafham Water over the period of time studied. These were Cryptophyceae, Diatoms, colonial greens, unicellular greens and blue-green algae. Genera of these algae, are shown in Table 1.

There were variations noted between sites (see Table 2) but overall, a seasonal pattern of algal dominance and succession was discernible.

Colonial 'greens' (eg. Scenedesmus) were dominant throughout the period (similar to mid-late 1990 pattern). In May 1991 blue green algae were as common as other types but their abundance decreased thereafter, and from July to October they were recorded only very intermittently. This is in marked contrast to 1990, when a blue green algal bloom occurred in August. See Figures 3, 4, 5 and 6.

From these data it might be inferred that, inspite of these changes, the primary productivity of the reservoir has not significantly altered in 1991 compared to 1990.

3.3 Zooplankton

Three groups of zooplankton were recorded over the year. These were Rotifers, Cladocera and Copepods. The genera and species present are shown in Table 3.

As with the phytoplankton results, variations were noted between sites (see Table 4) but several patterns were discernible. The incidence of Rotifers was reduced compared to 1990. Cladocera, in contrast, were much more abundant in 1991. Copepods recorded similar levels in 1990 and 1991. See Figures 7 and 8.

From these data it would also appear that the secondary productivity of the reservoir has shown an overall increase in 1991.

3.4 Benthic Invertebrates

A poor diversity of benthic invertebrates was recorded in 1991 (10 taxa), see Table 5. Chironomids and Oligochaetes dominated throughout and indeed were the only taxa showing any consistency of presence. Chironomid numbers decreased throughout May to October. Oligochaete numbers were more variable in this period but tended to decrease. See Figures 9,10 and 13.

The 'Pea' mussel (Pisidium) was much less abundant in 1991 compared to 1990 when it was a characteristic component of the benthic fauna. See Figures 15 and 16.

It is also noteworthy that an increasing incidence of empty (dead) Mollusc shells (Sphaeridae, Dreissenidae, Valvatidae and Lymnaea) were recorded towards the end of the monitoring period.

The changes in fauna were observed in varying degrees throughout all the sites examined, but were more marked at those sites associated with and to the north east of the aeration tower. See Table 5.

To try to refine this interpretation, cluster analysis was carried out on the data. See Figures 17 - 24. The analysis compares data from each site to produce an overall percentage measure of similarity between sites. It should be noted however, that the analysis is most informative when there are reasonably diverse fauna and this is not the case in Grafham Water - many sites only recorded Chironomids and Oligochaetes. Bearing this in mind, the analysis indicates that towards midsummer and into the autumn, the sites associated with the aeration tower were becoming distinct from the other sites in the reservoir. The former sites being characterised by particularly poor diversity and low abundances.

3.5 Marginal Invertebrates

Samples were routinely collected from the margins. Extremely restricted fauna were recorded but this is as a result of the catastrophic effects of reservoir 'draw down' during the drought in 1990. These marginal sites had been completely dry from the previous summer and well into the winter of 1990/91. There would have been complete loss of aquatic invertebrate (and macrophyte) from the sites and recovery would not have occurred when sampling was carried out in 1991. Such effects will have overridden any impact ferric dosing might have had and the data is not included in this report.

4 IMPLICATIONS TO THE TROUT FISHERY

The benthic invertebrate fauna might be expected to be an important part of the food resource of the trout fishery. If so then the reductions indicated in the invertebrate numbers (and therefore biomass) ought to have had a discernible effect on the growth and condition of the trout. Attempts have been made by Fisheries staff to obtain specimens for such assessment but to date these attempts have been unsuccessful.

5 OVERALL ASSESSMENT

Significant reductions in phosphate levels leading to reduced abundance of blue green algae have been achieved by AWS. However this operation appears to have led to a widespread reduction in the diversity and abundance of the benthic invertebrate fauna. At the same time an associated deterioration in the trout fishery has been claimed by anglers.

6 FUTURE MONITORINGS RECOMMENDATIONS

If ferric dosing of Grafham Water is continued in 1992 by AWS - whether at current or reduced levels - investigations and monitoring of the impact of such dosing ought to continue. Monitoring of the reservoir in 1990 and 1991 was carried out on a "minimum necessary" approach - as staff resources allowed. This has been enough to indicate that changes have occurred in the ecology of the reservoir that appear to be associated with the ferric dosing. However, it is difficult to be more precise than this, furthermore the extent of the changes across the whole reservoir cannot be discerned and conclusions cannot be drawn on what might be 'safe levels' of ferric dosing.

To seek to remedy these deficiencies, monitoring enhancements would be needed.

6.1 Benthic Invertebrates

Monitoring needs to be extended to enable representative cover of all areas of the reservoir. The transect approach needs to be employed and three replicates taken at each site. Sampling should be carried out monthly, ideally throughout the year, or at a minimum from April to November inclusive.

6.2 Sediment Analysis

Iron levels in the sediment need to be correlated with the associated invertebrate fauna. Unless this information is available from AWS, then core samples from representative sites need to be taken for iron analysis.

6.3 Plankton

Unless information is available from AWS then a similar level of monitoring to 1991 will be required in 1992.

6.4 Chlorophyll 'a' Analysis

Primary productivity is best measured by this parameter and monitoring of chlorophyll 'a' levels (in association with the phytoplankton sampling) should be carried out in 1992.

6.5 Marginal Invertebrates

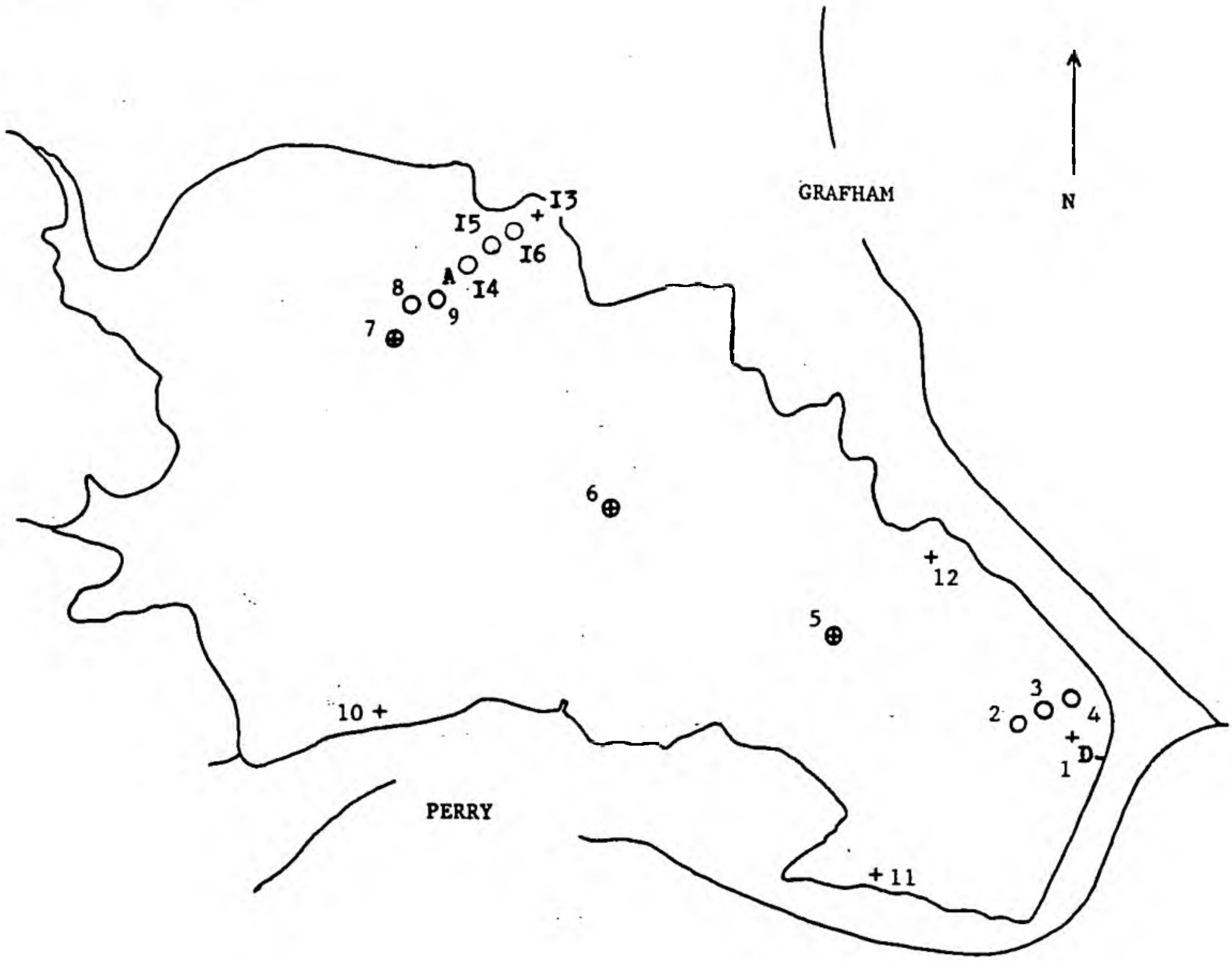
Significant reservoir draw down occurred again towards the end of 1991 and therefore the value of monitoring such areas re. ferric dosing will again be compromised in 1992

Biology Central

January 1992

WTC/SML/GRWTFERR

FIGURE 1 : GRAFHAM WATER RESERVOIR SAMPLE POINTS



KEY :

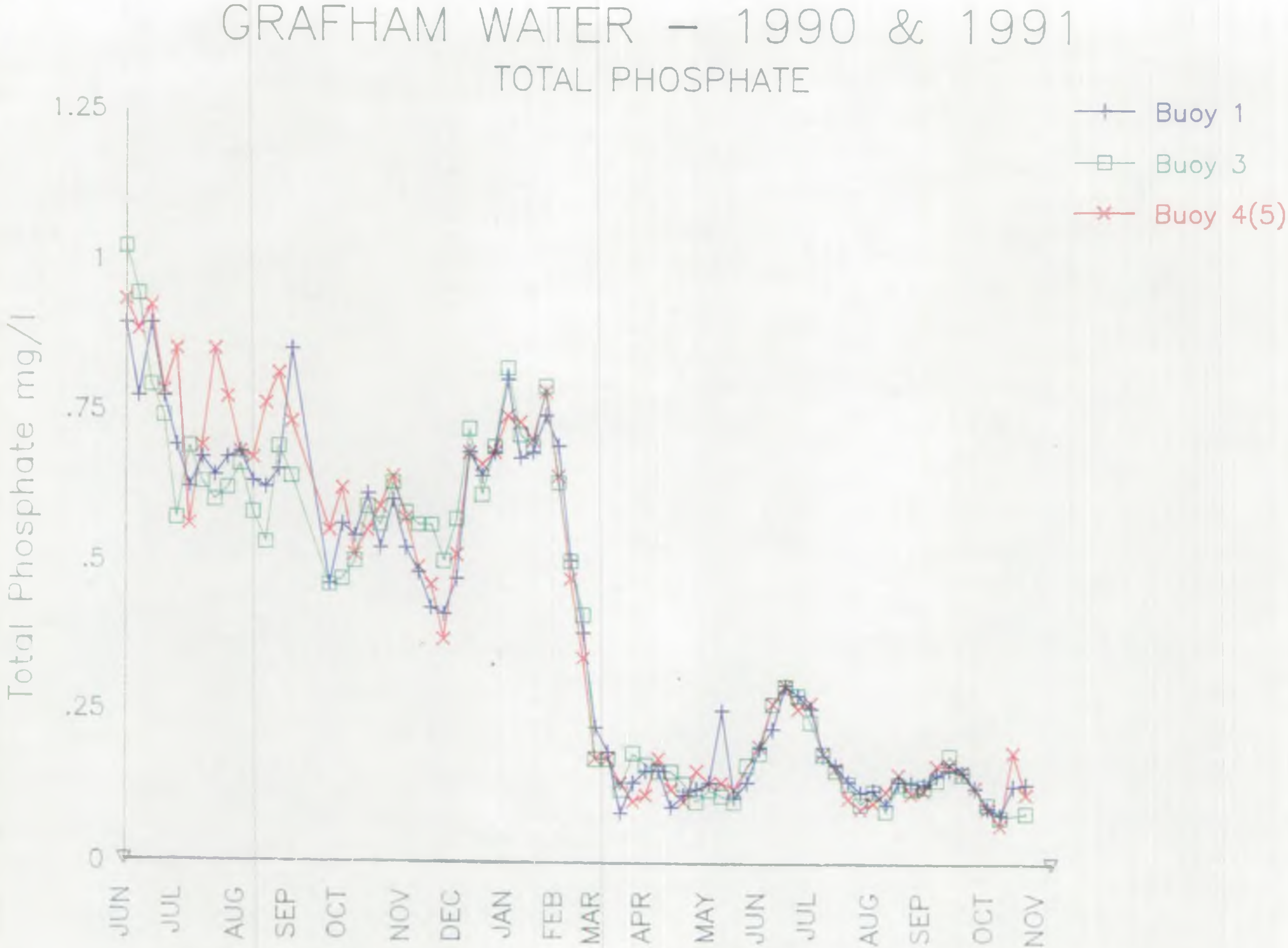
BENTHOS O

PLANKTON +

A Aeration Tower

D Draw - Off Tower

FIGURE 2


GRAFHAM WATER - 1990 & 1991
TOTAL PHOSPHATE
Buoy 1
Buoy 3
Buoy 4(5)
Total Phosphate mg/l
1.25
1
.75
.5
.25
0
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
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OCT
NOV

FIGURE 3

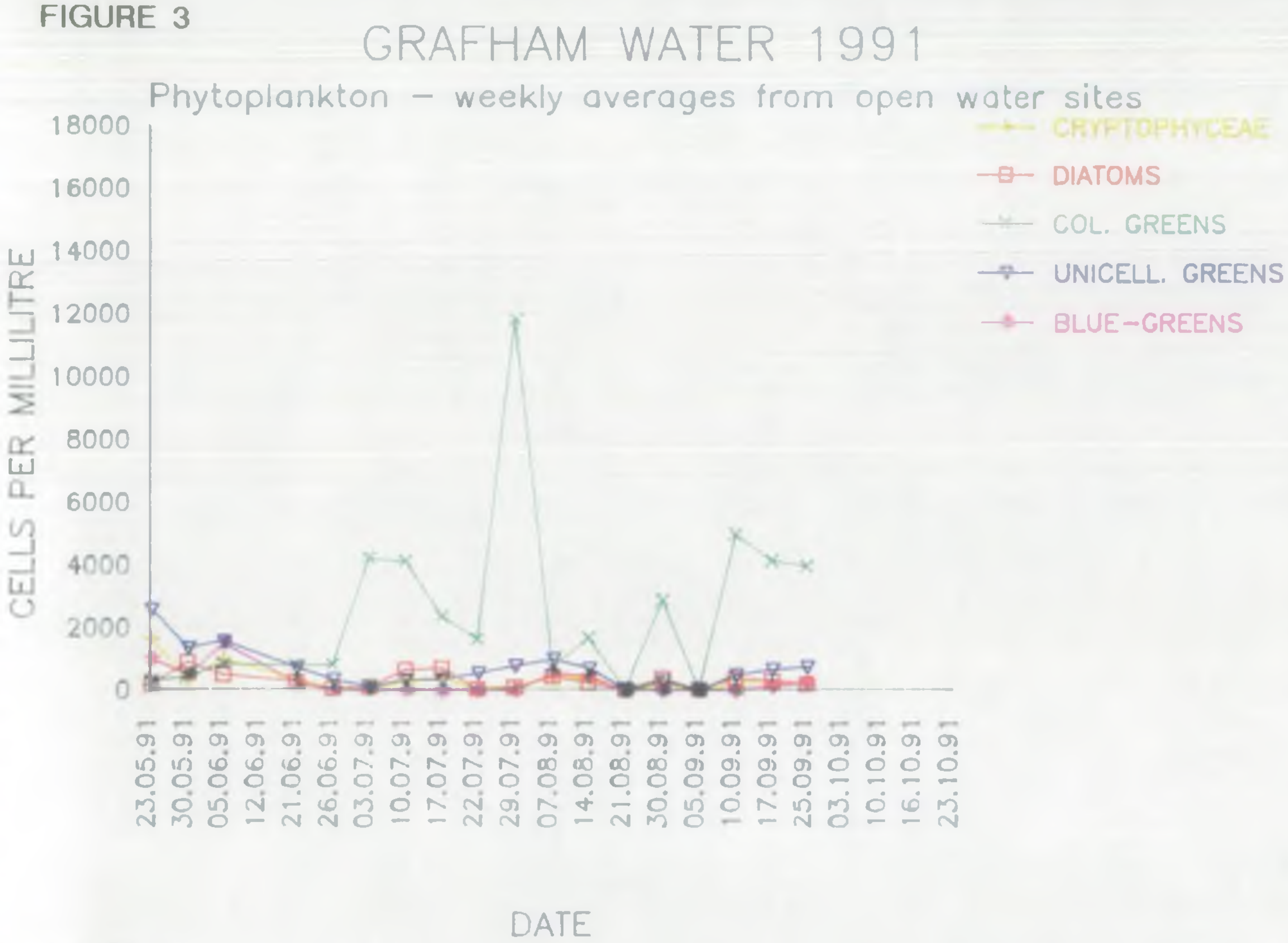


FIGURE 4

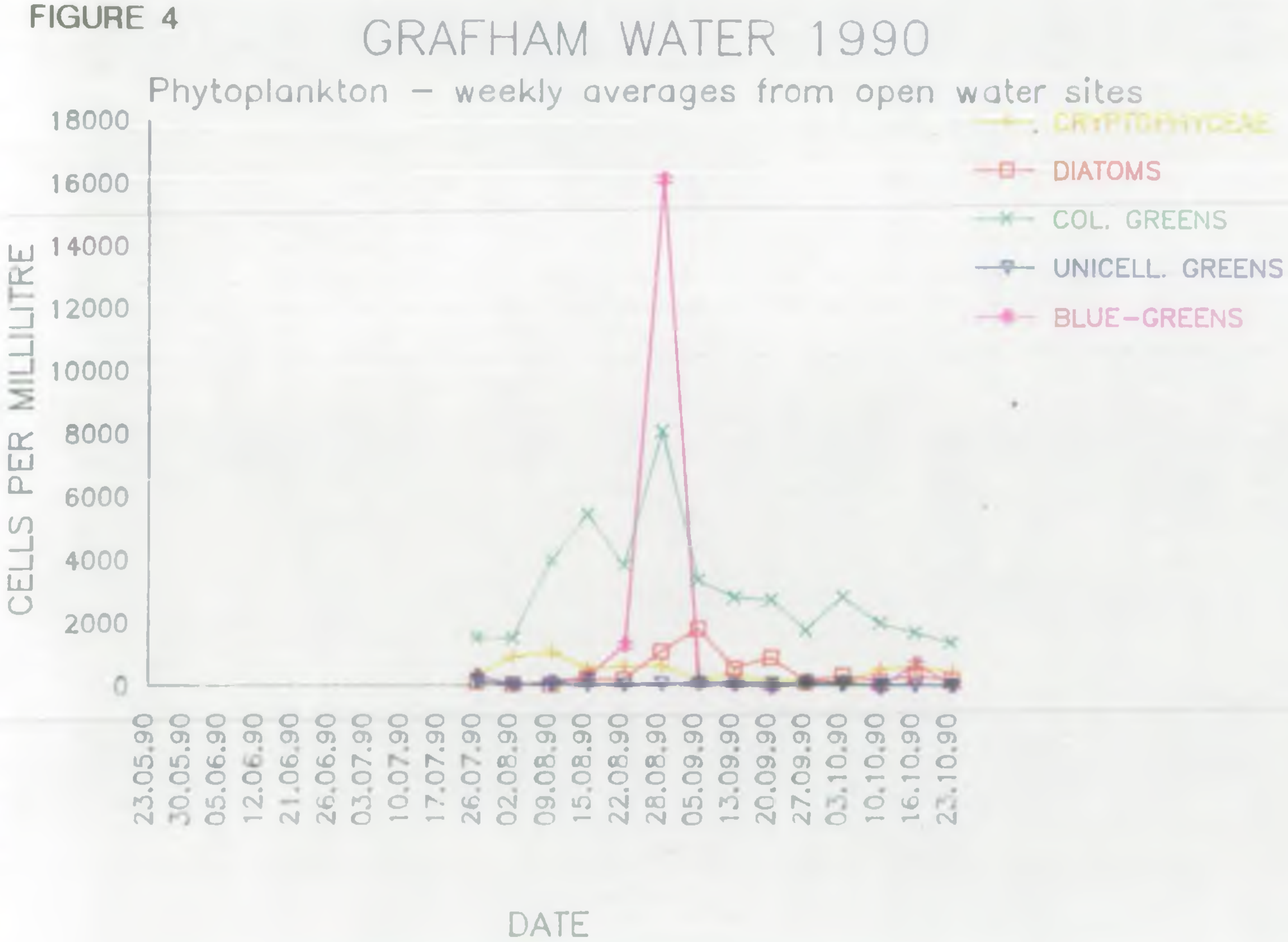


FIGURE 5

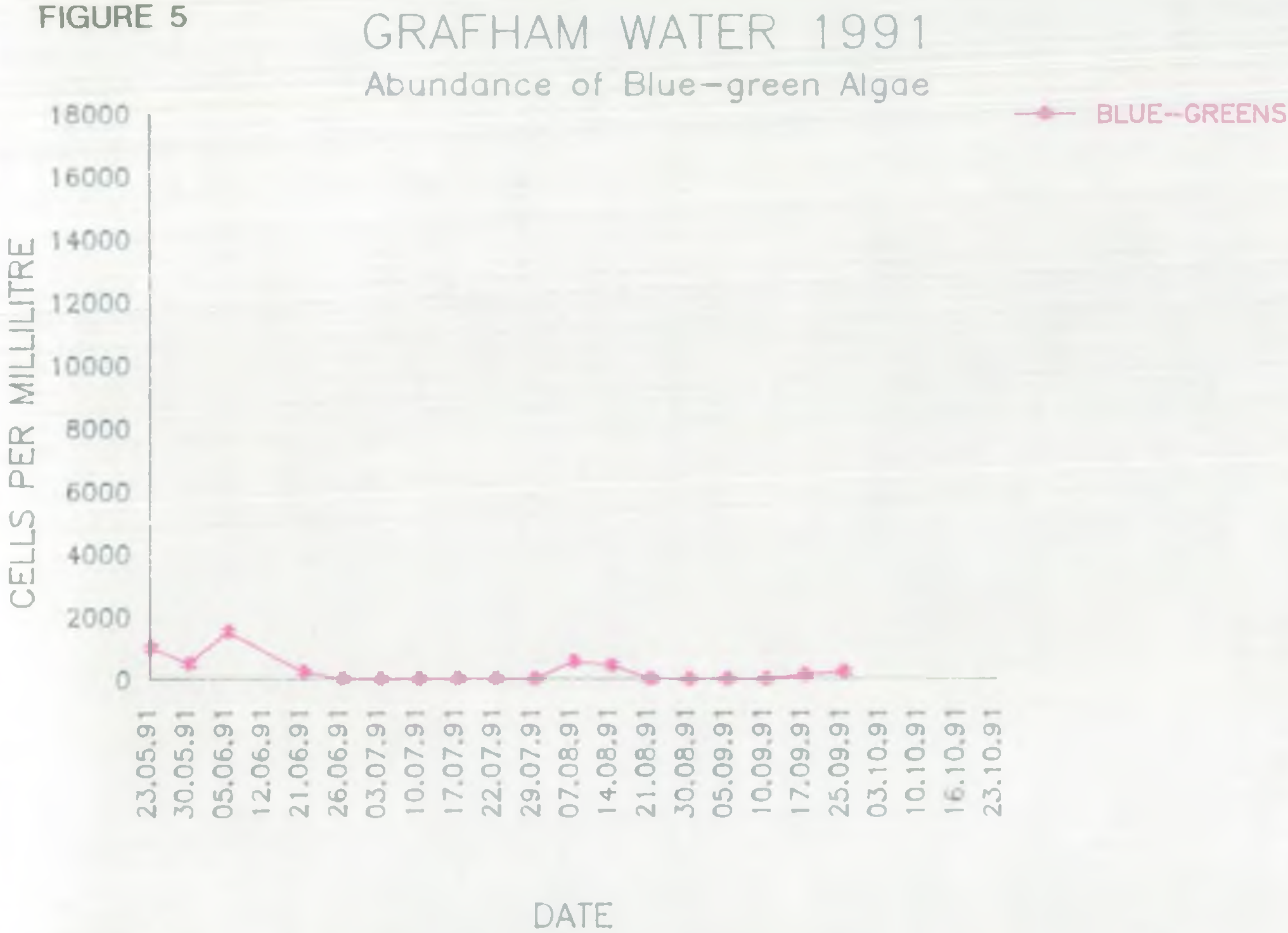


FIGURE 6

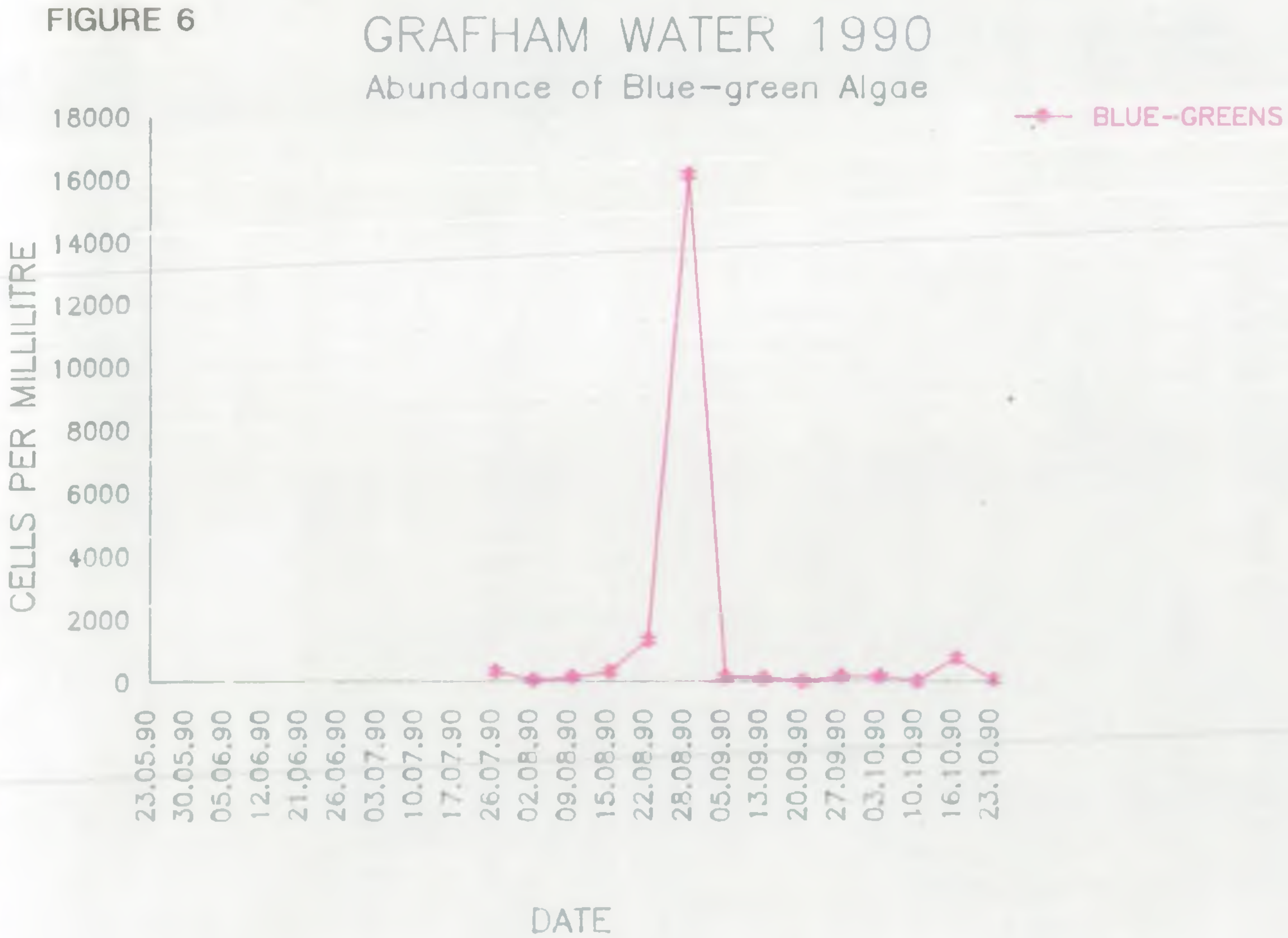


FIGURE 7

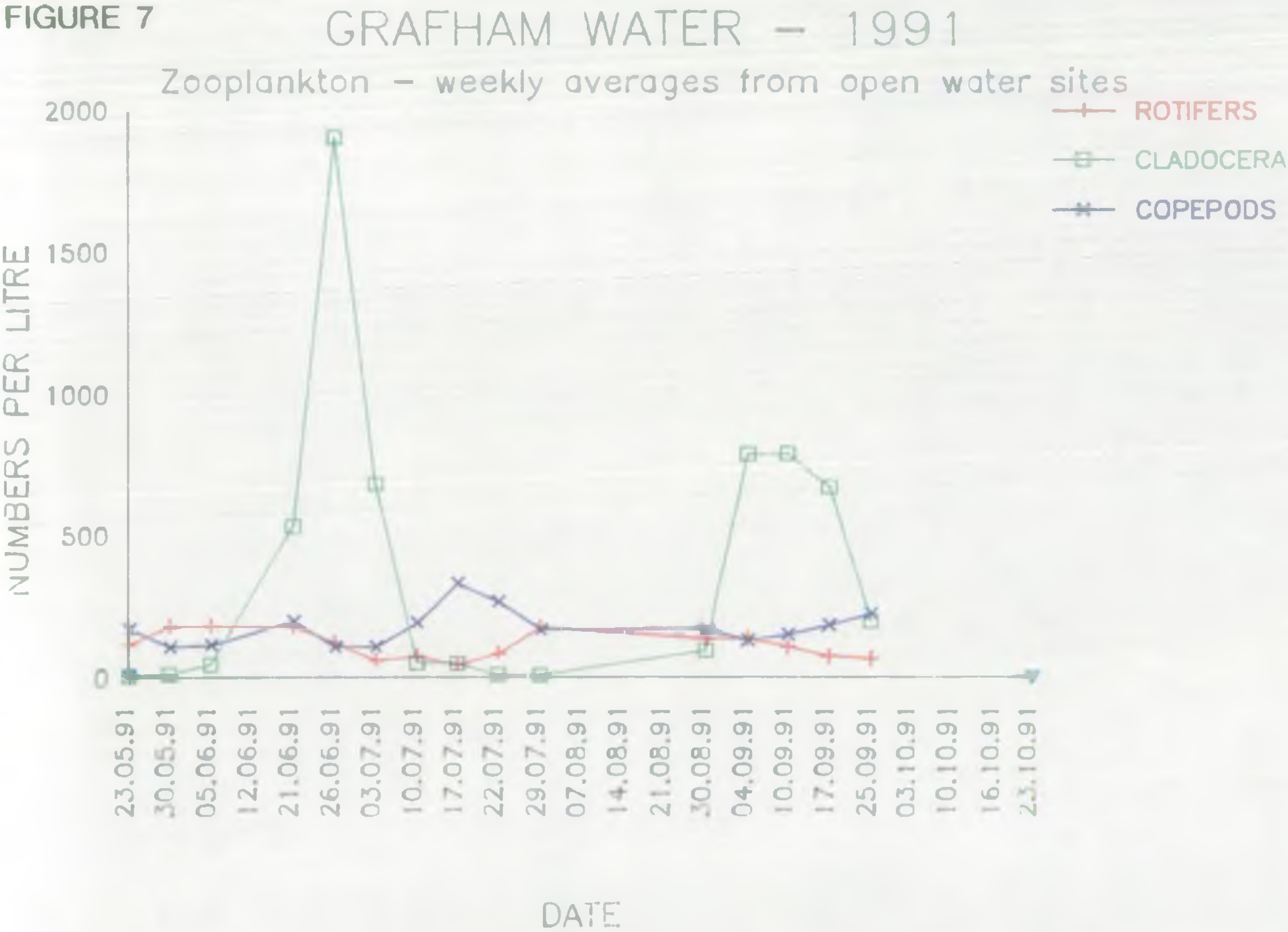


FIGURE 8

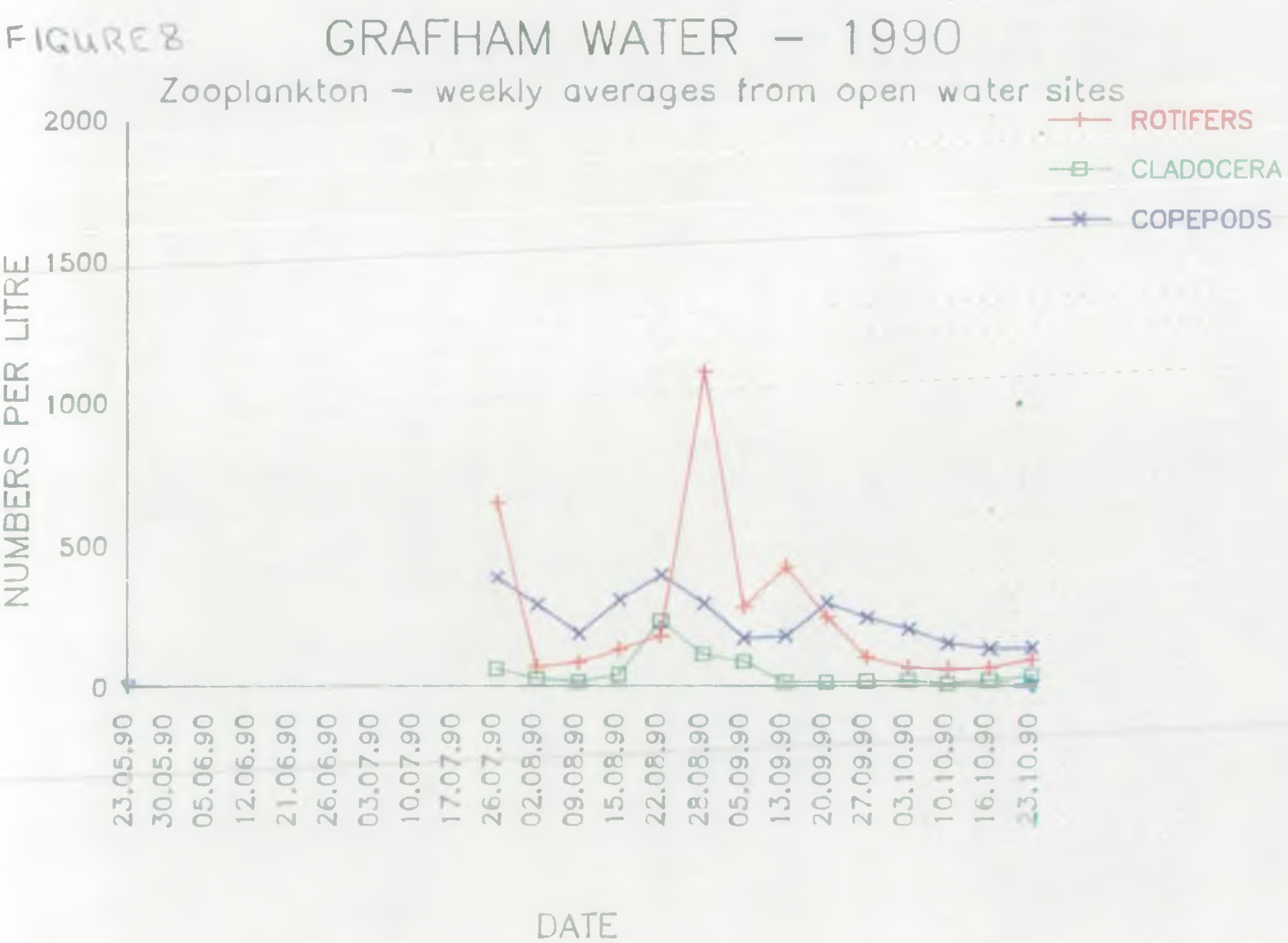


FIGURE 9

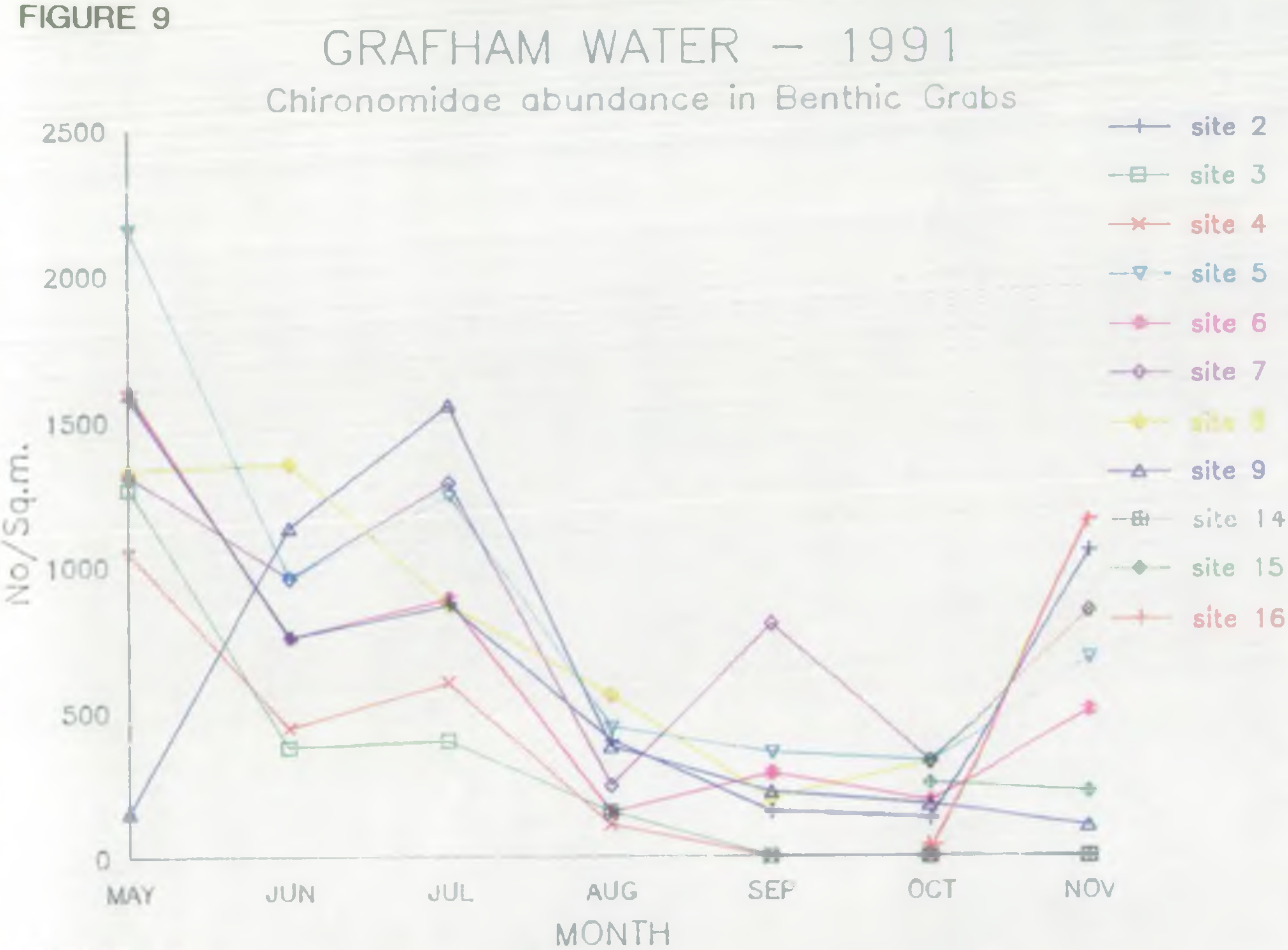


FIGURE 10

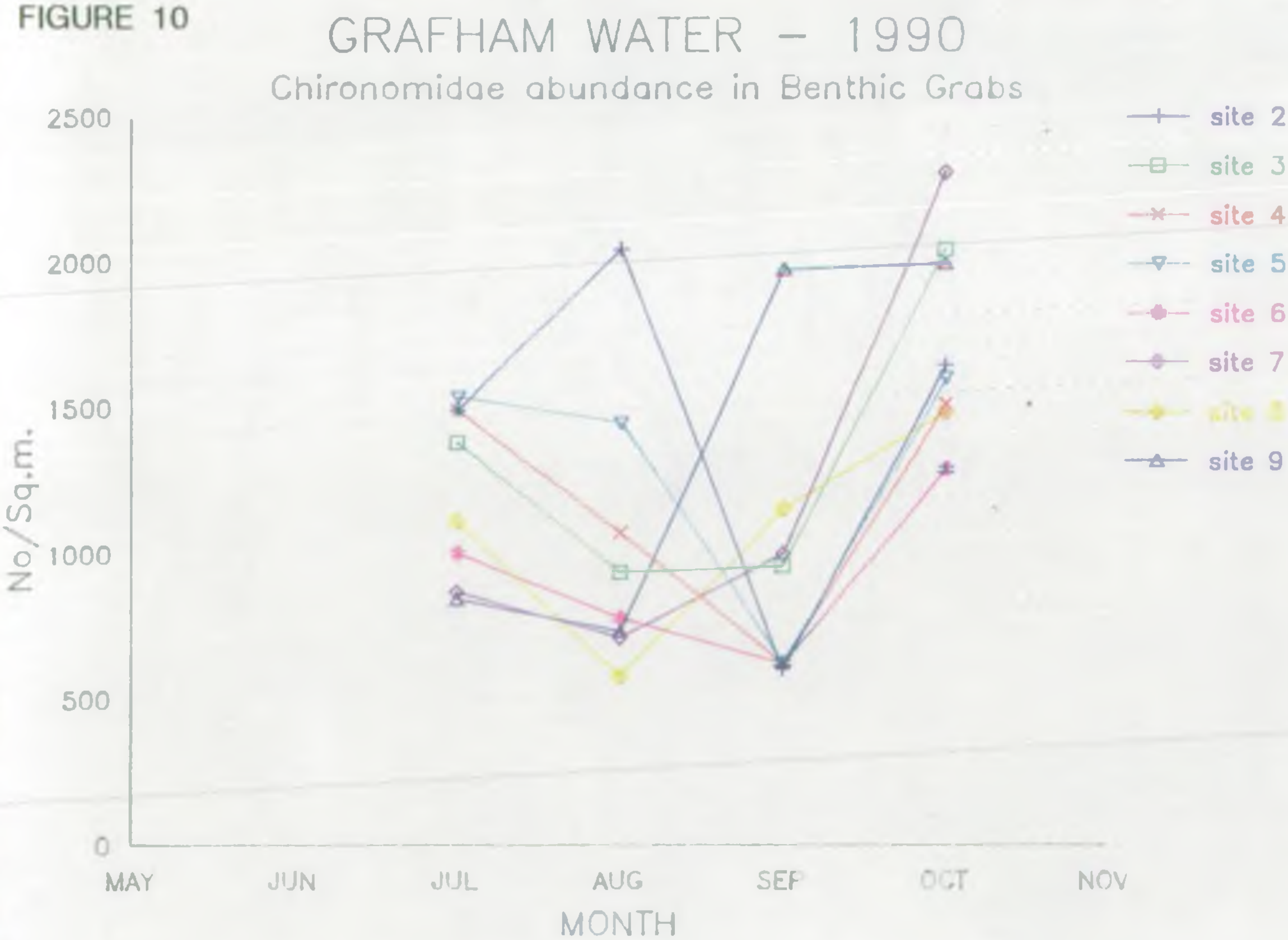


FIGURE 11

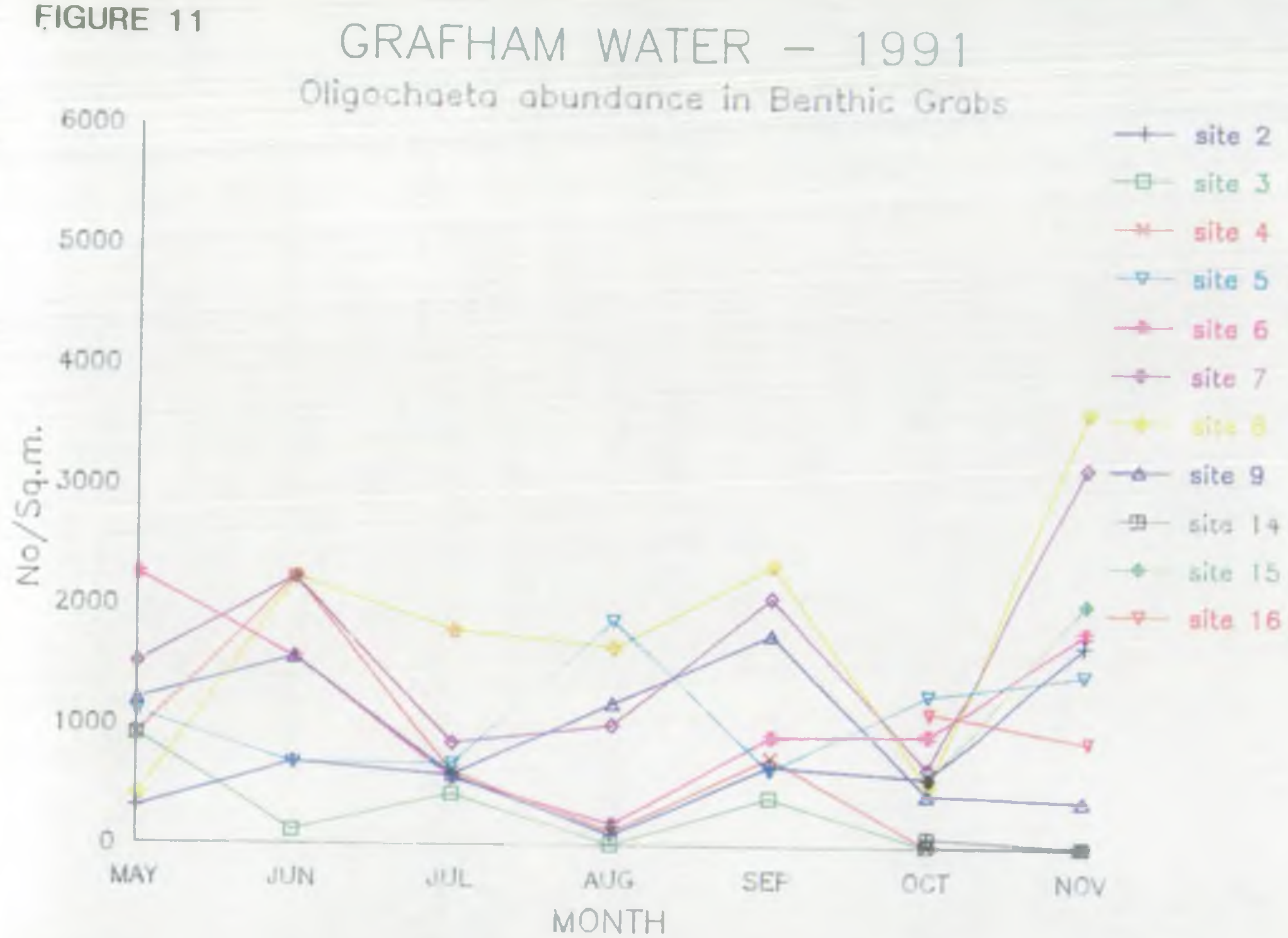
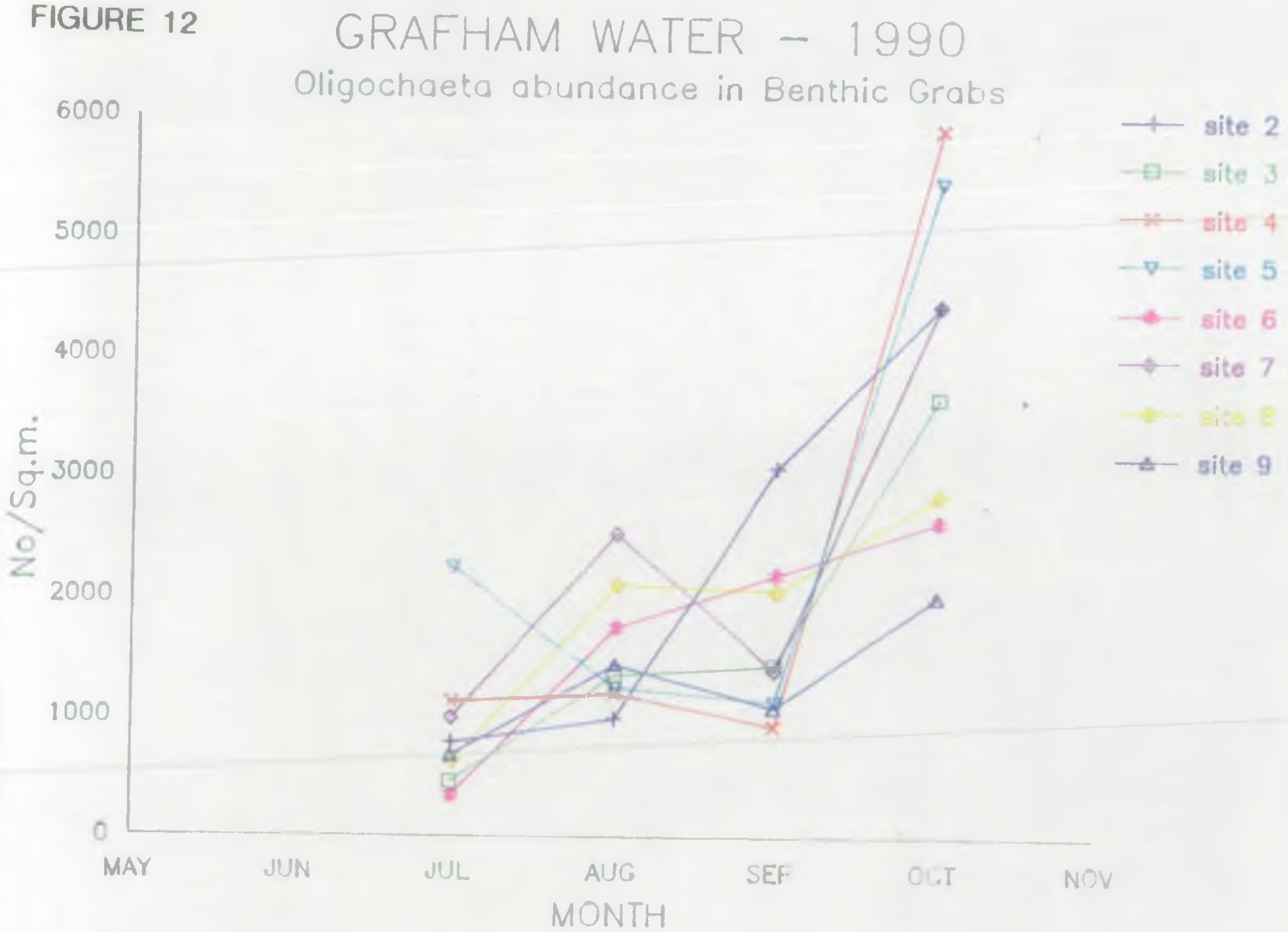


FIGURE 12



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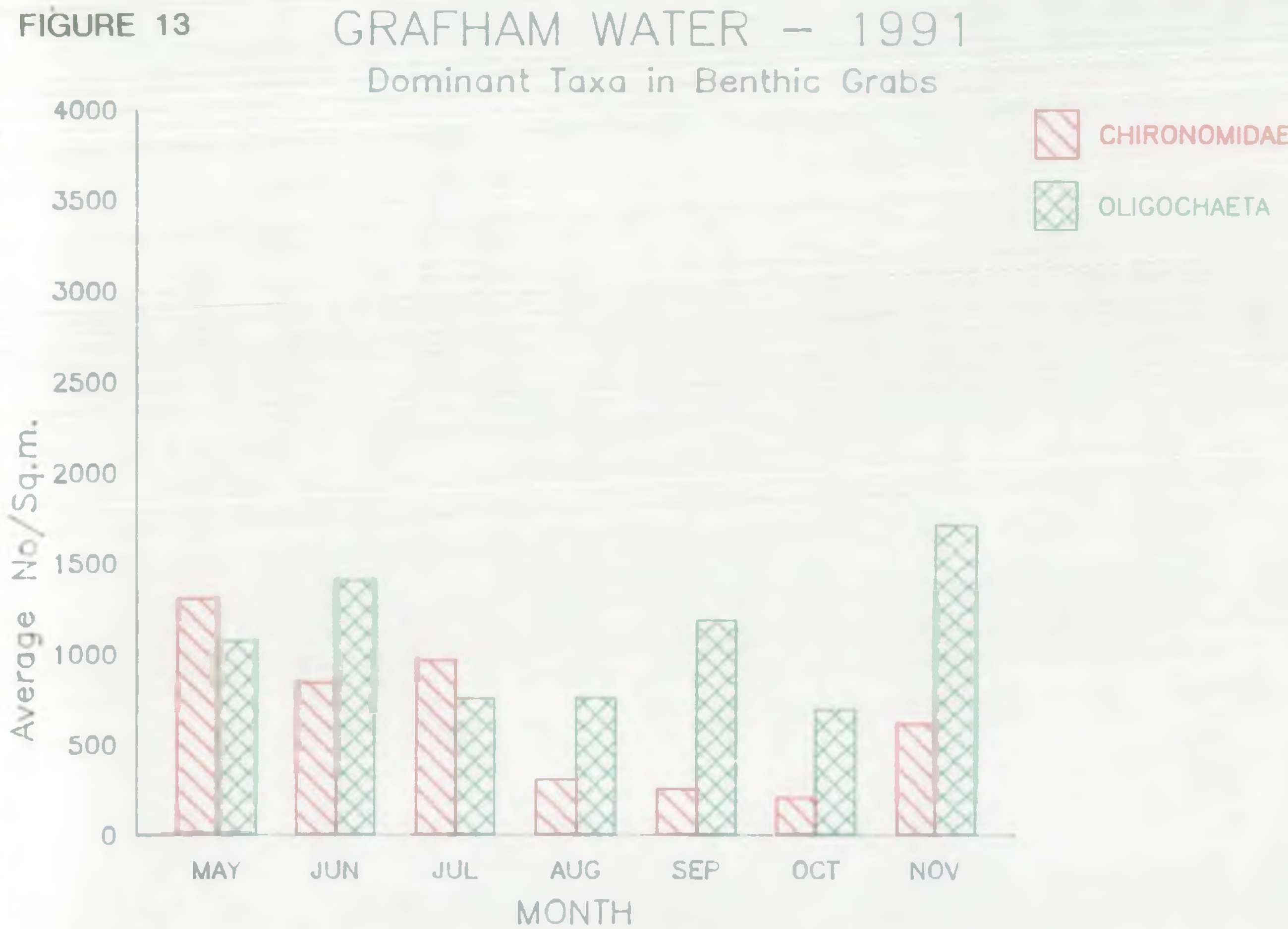


FIGURE 14

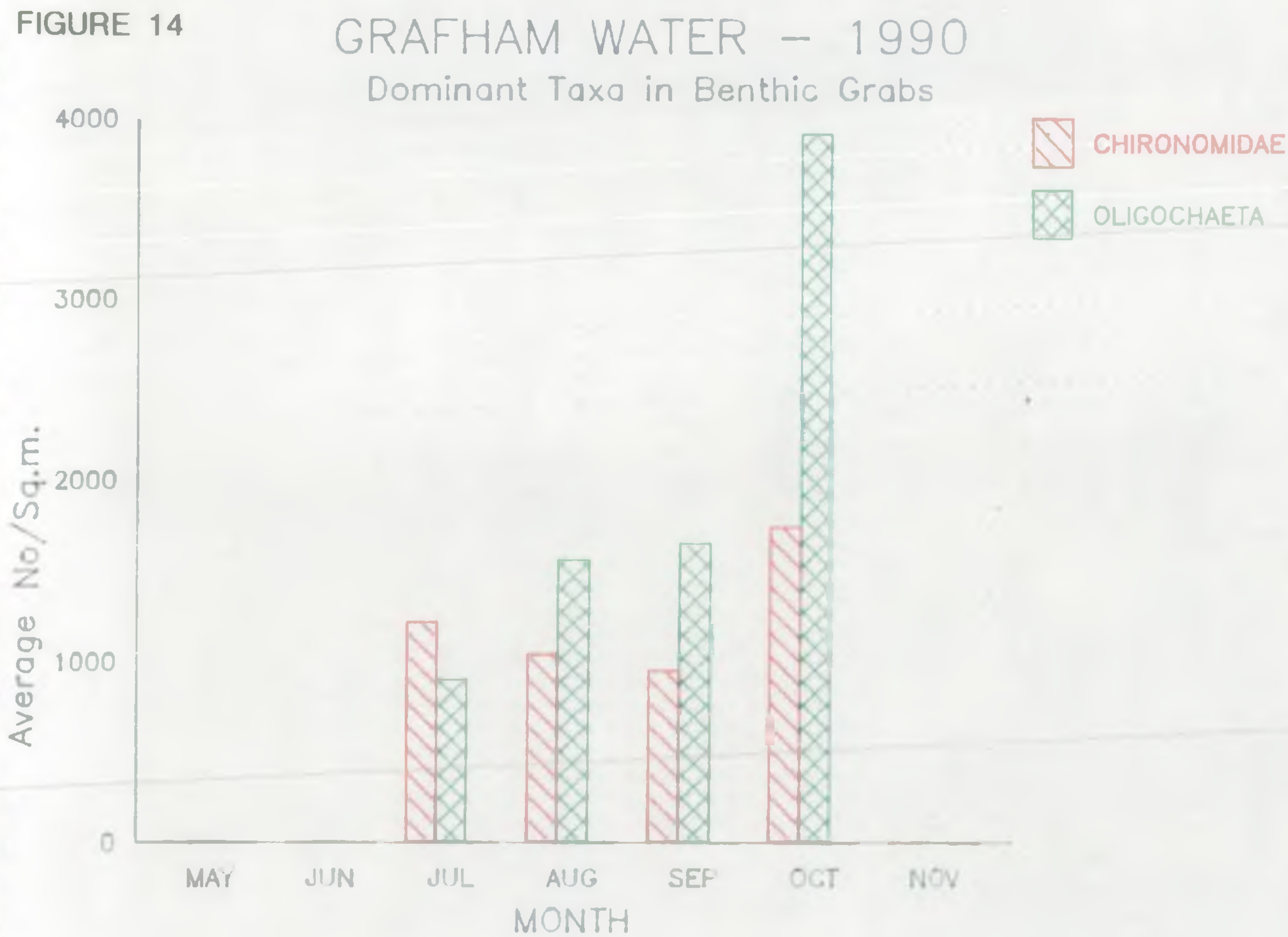


FIGURE 15

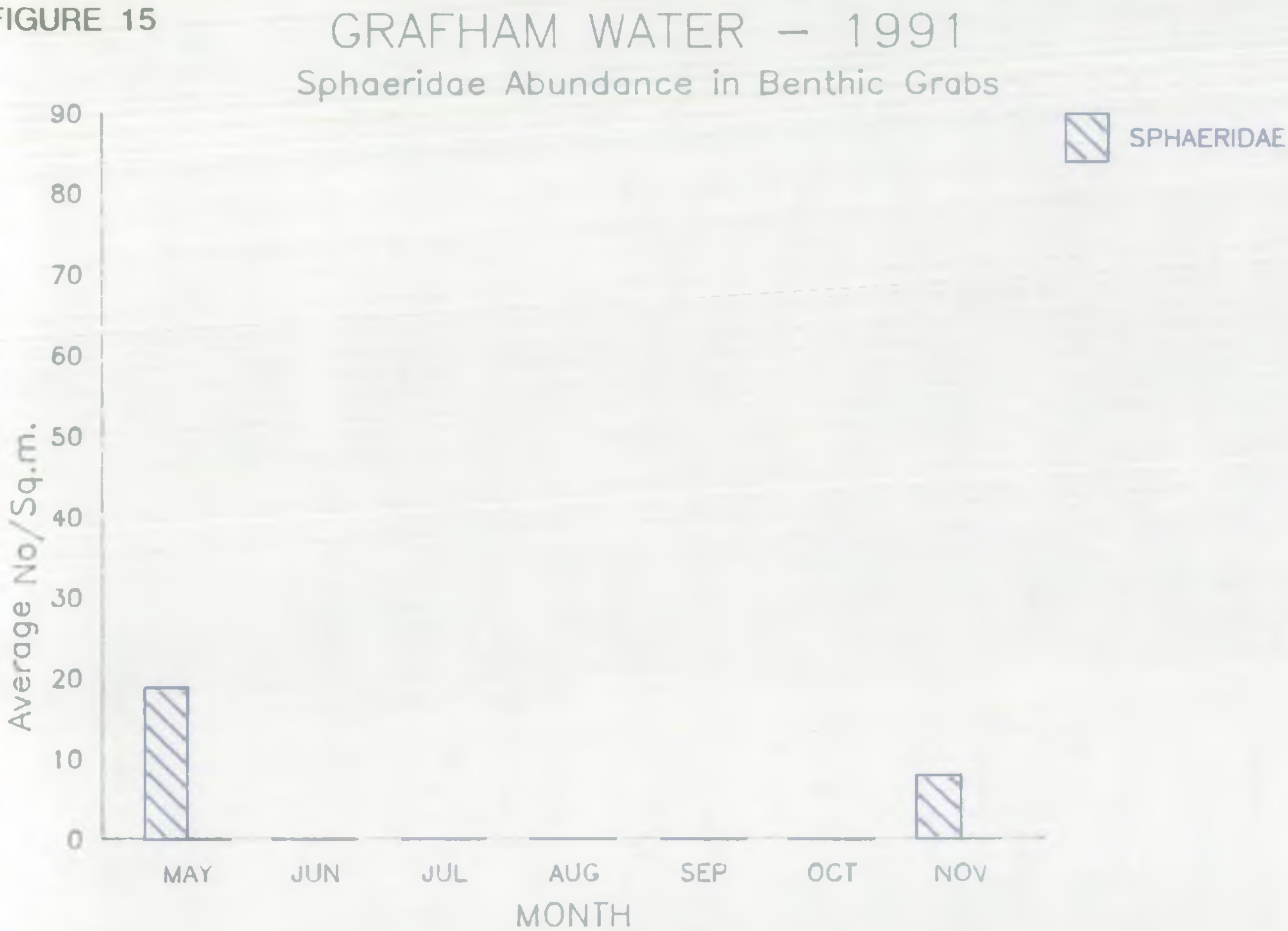


FIGURE 16

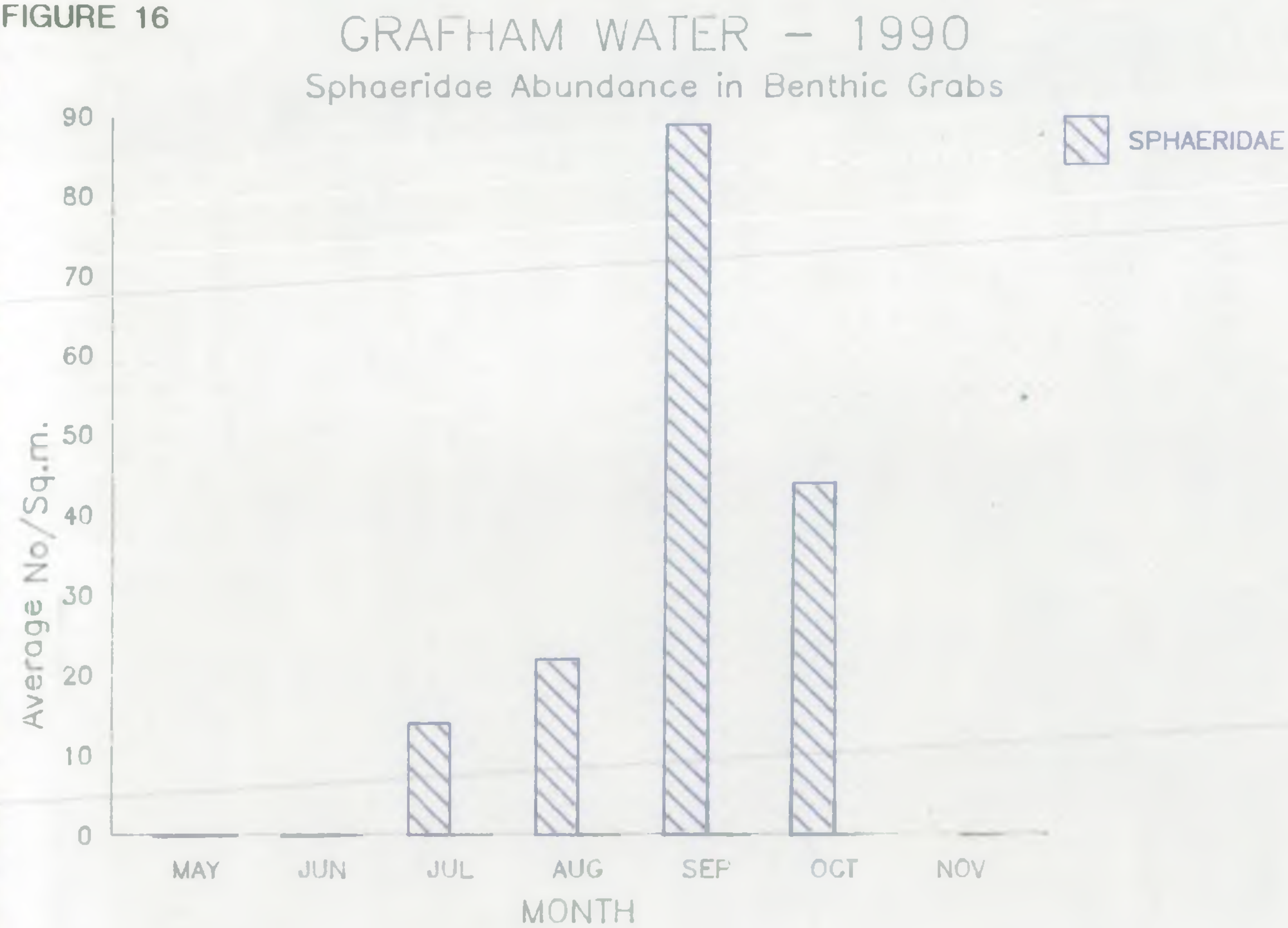
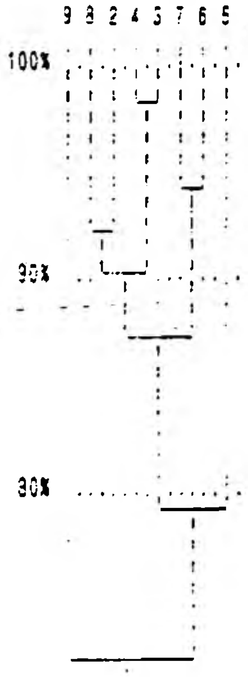
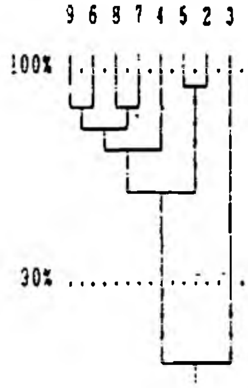


FIGURE 17

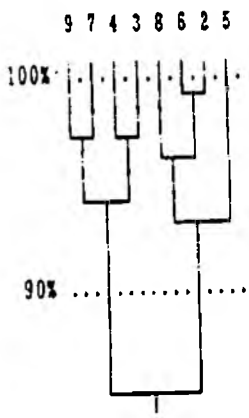
CLUSTER ANALYSIS OF BENTHIC GRAB DATA 1991



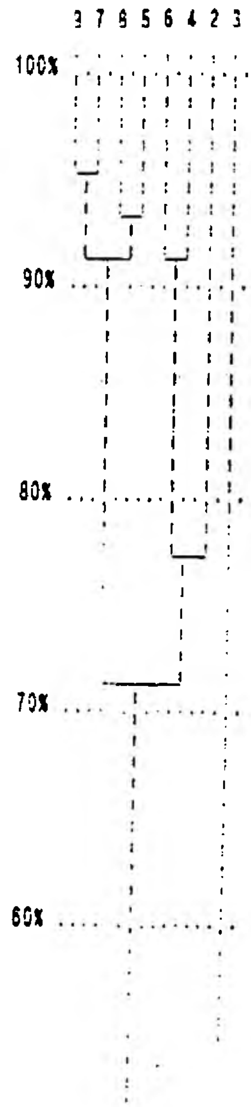
23.05.91



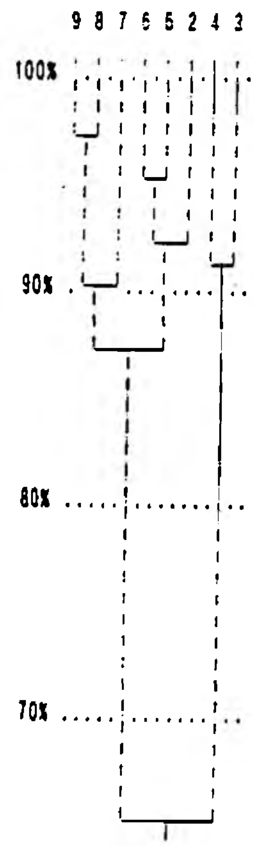
26.06.91



30.07.91



30.08.91

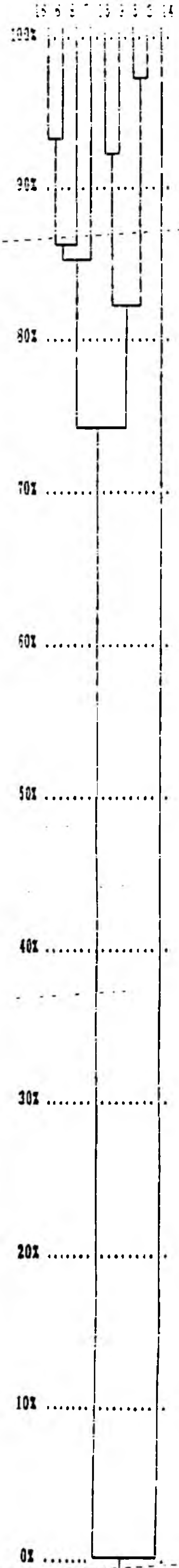


25.09.91

FIGURE 17

(Continued)

23.10.91



25.11.91

FIGURE 18

BENTHIC GRAB SAMPLES : CLUSTER GROUP CHARACTERISTICS
23/05/91

GROUP		GROUP Ave. Ni	Ave. Ns	DOMINANT TAXA
1 (n=2)	●	2066	2	Chironomidae
2 (n=2)	●	3368	3	Oligochaeta

Ungrouped sites :

(2)	O	1883	2	Chironomidae
(5)	O	3468	4	Chironomidae
(8)	O	1755	3	Chironomidae
(9)	O	1422	4	Oligochaeta

Ni=Number of individuals
Ns=Number of Taxa

FIGURE 19

BENTHIC GRAB SAMPLES : CLUSTER GROUP CHARACTERISTICS
26/06/91

GROUP		GROUP Ave. Ni	GROUP Ave. Ns	SUB GROUP	GROUP Ave. Ni	GROUP Ave. Ns	DOMINANT TAXA
1 (n=4)	●	2939	2	1A (n=2)	2501	2	Oligochaeta
				1B (n=2)	3378	2	Oligochaeta
2 (n=2)	●	1556	2				Oligochaeta/Chironomi
Ungrouped sites							
(3)	○	511	1				Chironomidae
(4)	○	2666	2				Oligochaeta

FIGURE 20

BENTHIC GRAB SAMPLES : CLUSTER GROUP CHARACTERISTICS
22/07/91

GROUP		GROUP Ave. Ni	Ave. Ns	DOMINANT TAXA
1 (n=2)	● (red)	1511	4	Chironomidae
2 (n=2)	● (green)	2166	3	Chironomidae
3 (n=2)	● (orange)	1022	3	Chironomidae/Oligochaeta
Ungrouped sites :				
(5)	○	2067	4	Chironomidae
(8)	○	2683	4	Oligochaeta

Ni=Number of individuals
Ns=Number of Taxa

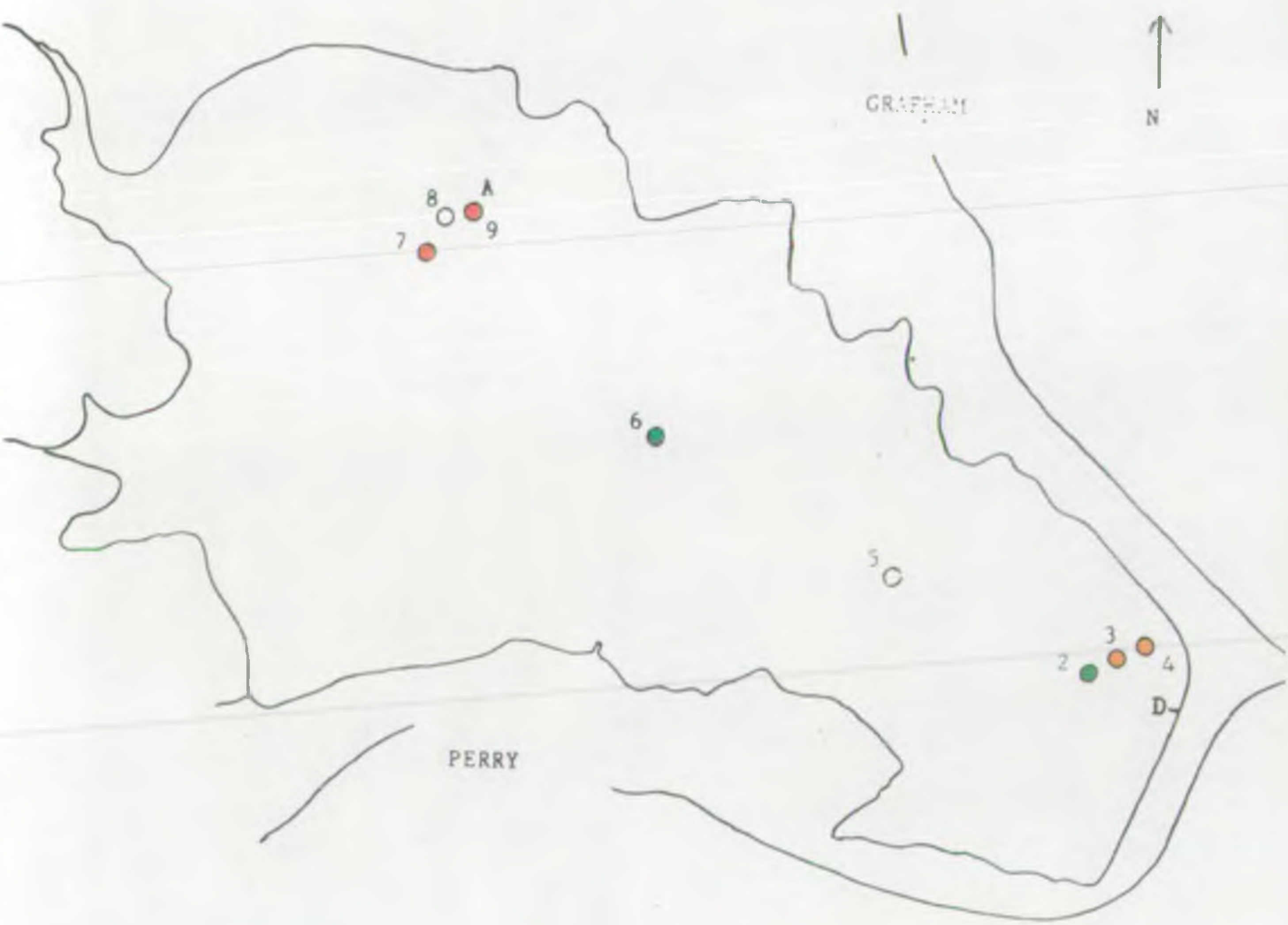


FIGURE 21

BENTHIC GRAB SAMPLES : CLUSTER GROUP CHARACTERISTICS
30/08/91

GROUP		GROUP Ave. Ni	Ave. Ns	DOMINANT TAXA
1 (n=2)	●	1400	2	Oligochaeta
2 (n=2)	●	1266	2	Oligochaeta
Ungrouped sites :				
(2)	○	511	3	Chironomidae
(3)	○	178	2	Chironomidae
(4)	○	222	2	Chironomidae/Oligochaeta
(6)	○	356	2	Oligochaeta

Ni=Number of individuals
Ns=Number of Taxa

FIGURE 22

BENTHIC GRAB SAMPLES : CLUSTER GROUP CHARACTERISTICS
25/09/91

GROUP		GROUP Ave. Ni	Ave. Ns	SUB GROUP	GROUP Ave. Ni	Ave. Ns	DOMINANT TAXA
1 (n=3)	●	1000	2	1A (n=2)	1089	2	Oligochaeta
				1b (n=1)	823	2	Oligochaeta
2 (n=3)	●	2459	2	2A (n=2)	2255	2	Oligochaeta
				2B (n=1)	2867	2	Oligocnaeta
3 (n=2)	●	577	1				Oligochaeta

Ni=Number of individuals
Ns=Number of Taxa

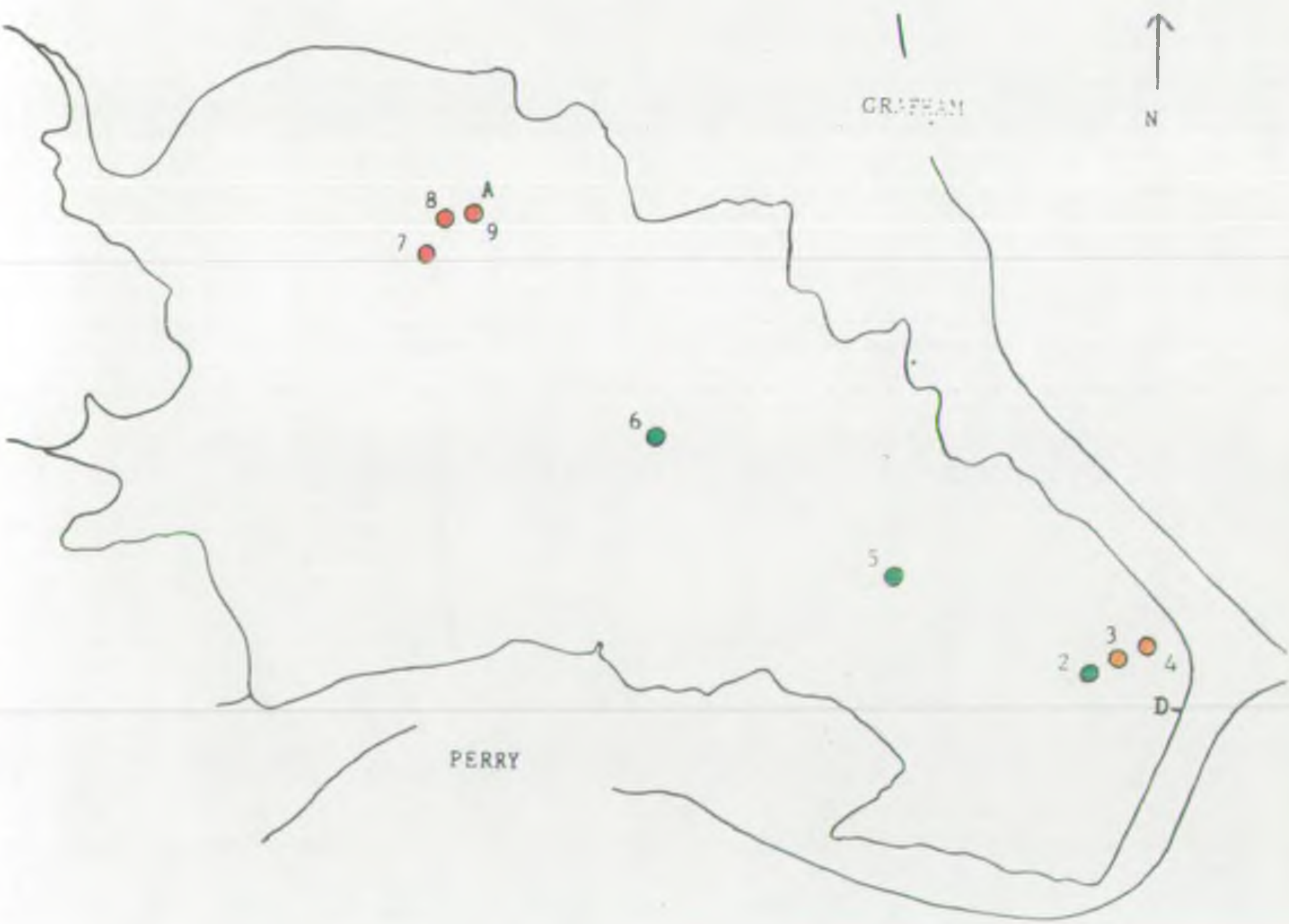


FIGURE 23

BENTHIC GRAB SAMPLES : CLUSTER GROUP CHARACTERISTICS
23/10/91

GROUP	GROUP Ave. Ni	Ave. Ns	SUB GROUP	GROUP Ave. Ni	Ave. Ns	DOMINANT TAXA
1 (n=7)	950	2	1A (n=4) ●	808	2	Oligochaeta
			1B (n=2) ●	1355	2	Oligochaeta
			1C (n=1) ●	711	2	Oligochaeta
Ungrouped sites :						
(14) ○	74	1				Oligochaeta
(16) ○	1111	2				Oligochaeta

Ni=Number of individuals
Ns=Number of Taxa

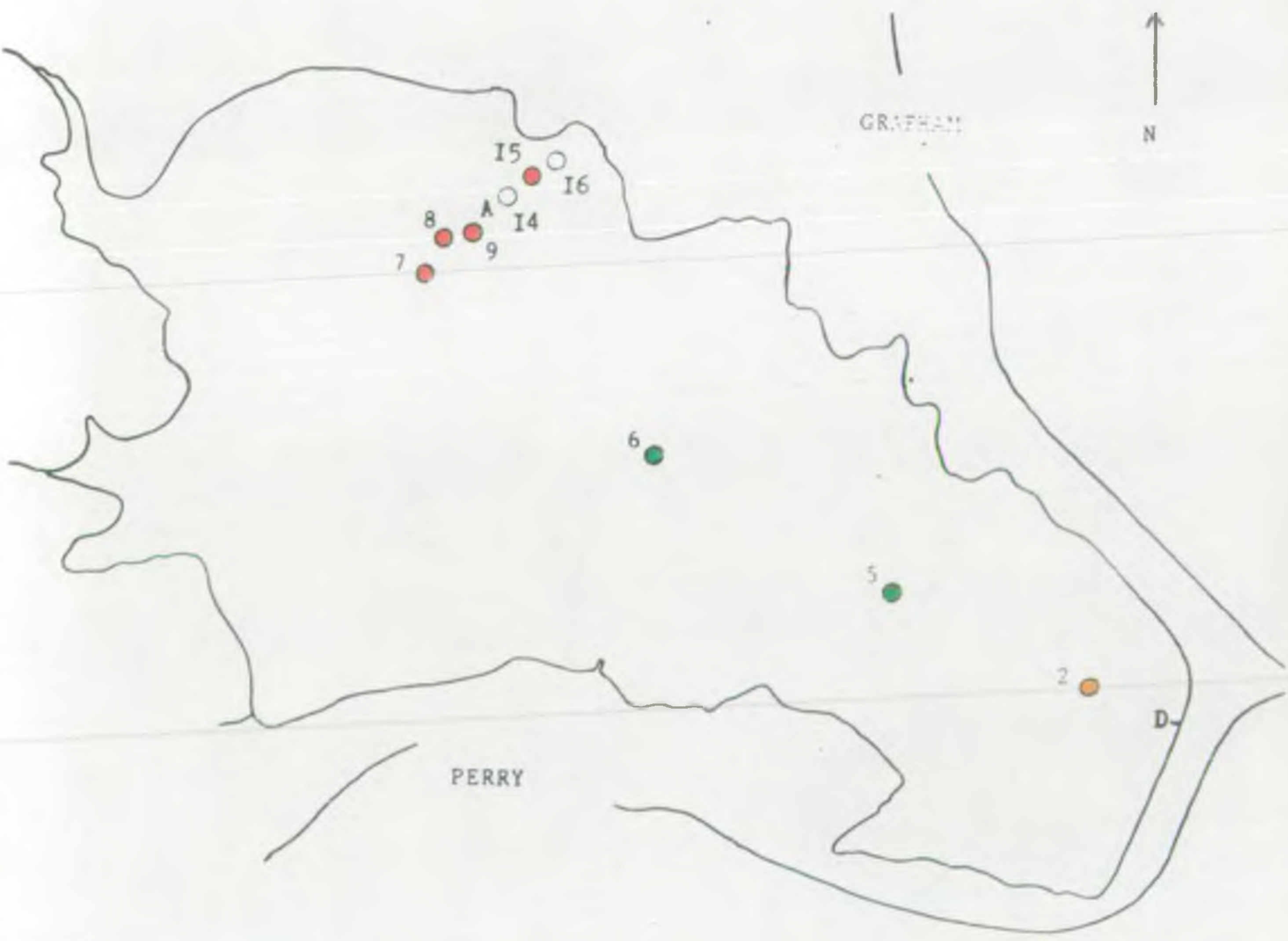


FIGURE 24

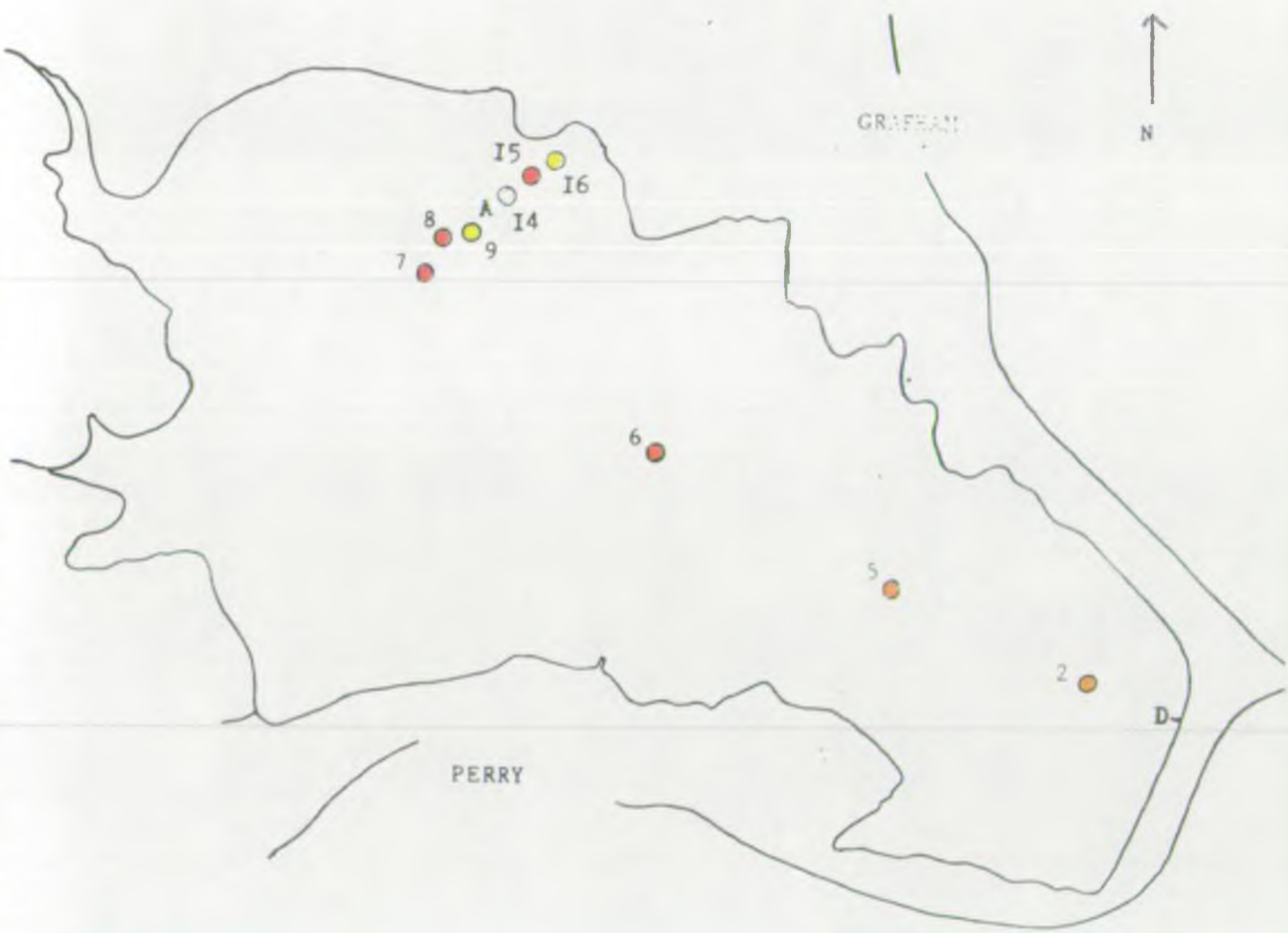
BENTHIC GRAB SAMPLES : CLUSTER GROUP CHARACTERISTICS
25/11/91

GROUP	GROUP Ave. Ni	GROUP Ave. Ns	DOMINANT TAXA
1 (n=2)	2429	2	Oligochaeta
2 (n=2)	1371	2	Oligochaeta
3 (n=2)	3278	4	Oligochaeta

Ungrouped sites :

(I4)	0	0

Ni=Number of individuals
Ns=Number of Taxa



1991 DATA

TABLE 1

PHYTOPLANKTON OF GRAFHAM WATER

Cryptophycae sp:	Cryptomonas sp
	u/d small flagellates
Diatoms:	Asterionella sp
	Fragilaria sp
	Navicula sp
	Gyrosigma sp
	Surirella sp
	Diatoma sp
	u/d centric diatoms
Colonial greens:	Scenedesmus sp
	Pediastrum sp
	Crucigenia sp
	Actinastrum sp
	Botryococcus sp
Unicellular greens:	Ankistrodesmus sp
	Chlorella sp
	Euastrum sp
	Closterium sp
	Staurastrum
Blue-greens:	Aphanizomenon sp
	Anabaena sp

TABLE 2

GRAFHAM WATER - SURVEY 1991
CELLS PER MILLILITRE

23.5.91	1	5	6	7	10	11	12	13
PHYTOPLANKTON								
CRYPTOPHYCEAE	5625	313	750	25	8	438	188	63
DIATOMS	313	188	183	25	167	1938	751	813
COL. GREENS	313	375	500	8			500	188
UNICELL. GREENS	4688	3313	2125	192	42	1750	3063	4000
BLUE-GREENS	2500	938	625			3125	4125	4688

30.5.91	1	5	6	7	10	11	12	13
PHYTOPLANKTON								
CRYPTOPHYCEAE	750		94	500	94	688	438	1188
DIATOMS	250	105	407	876	282	1313	626	813
COL. GREENS	375			1313	375	375	500	1313
UNICELL. GREENS	1000	188	813	3375	782	2375	2250	1500
BLUE-GREENS	1250		750		1344	5625	625	625

5.6.91	1	5	6	7	10	11	12	13
PHYTOPLANKTON								
CRYPTOPHYCEAE	1250	50	1438	500	1063	188	375	375
DIATOMS	500	337	563	563	125	1376	938	433
COL. GREENS	750		1875	750	375	375	250	500
UNICELL. GREENS	1625	81	2375	2188	2625	2875	4813	2875
BLUE-GREENS		125	938	5000		2188	5313	2063

12.06.91
NO SAMPLES

21.6.91	1	5	6	7	10	11	12	13
PHYTOPLANKTON								
CRYPTOPHYCEAE	156	563	312	438	125		938	844
DIATOMS	63	125	62	813	157	2001	375	782
COL. GREENS	594	500	396	1625	250	1125	1000	12[illegible]
UNICELL. GREENS	813	781	583	688	328	188	1063	688
BLUE-GREENS		938						

26.6.91	1	5	6	7	10	11	12	1[illegible]
PHYTOPLANKTON								
CRYPTOPHYCEAE	42	31	47	16	812		500	6[illegible]
DIATOMS	21	125	48		500	1751	63	11[illegible]
COL. GREENS	1042	1219	656	250	2000	875	500	59[illegible]
UNICELL. GREENS	63	344	203	672	1625	63	750	21[illegible]
BLUE-GREENS						938		

3.7.91	1	5	6	7	10	11	12	13
PHYTOPLANKTON								
CRYPTOPHYCEAE		13	375		38	125	125	94
DIATOMS	63	38	188	27	88	188	167	407
COL. GREENS	12188	625	3313	661	663	1688	542	1094
UNICELL. GREENS		113	250	9	38	1000	354	281
BLUE-GREENS						625		

10.7.91	1	5	6	7	10	11	12	13
PHYTOPLANKTON								
CRYPTOPHYCEAE	184	276	313	188		375	188	313
DIATOMS	436	122	876	1125		188	1188	31
COL. GREENS	626	1072	8500	6188	2875	2625	8375	949
UNICELL. GREENS	337	398	375	125	500	1188	313	313
BLUE-GREENS								184

17.7.91	1	5	6	7	10	11	12	13
PHYTOPLANKTON								
CRYPTOPHYCEAE	219	688	312	500	500	156	63	94
DIATOMS	469	500	249	1563	594	313	250	
COL. GREENS	688	4125	854	3688	1250	1000	7750	1406
UNICELL. GREENS	219	438	104	563	563	813	813	531
BLUE-GREENS								

22.7.91	1	5	6	7	10	11	12	13
PHYTOPLANKTON								
CRYPTOPHYCEAE	18	62	62		250	563	313	62
DIATOMS	18			62	188	1125		813
COL. GREENS	330	3281	646	2188	4438	4125	3625	3375
UNICELL. GREENS	295	531	458	813	1188	1563	1000	750
BLUE-GREENS								

29.7.91	1	5	6	7	10	11	12	13
PHYTOPLANKTON								
CRYPTOPHYCEAE	63	125	63	188	63	125	188	
DIATOMS	63			251	125			313
COL. GREENS	1075	30438	7625	8063	2625	4750	15063	19438
UNICELL. GREENS	500	625	1500	438	1063	188	1063	1438
BLUE-GREENS								

7.8.91	1	5	6	7	10	11	12	13
PHYTOPLANKTON								
CRYPTOPHYCEAE	156	63		188	125	63		63
DIATOMS	31			63	250	875		
COL. GREENS	1219	5688	3125	2313	2500	5000	2500	3750
UNICELL. GREENS	781	1250	2000	937	1438	68	1250	1125
BLUE-GREENS			625					

14.8.91	1	5	6	7	10	11	12	13
PHYTOPLANKTON								
CRYPTOPHYCEAE		31	313	438	688	188	563	188
DIATOMS	375	156	1188	563	87	250	1125	250
COL. GREENS	3063	563	2063	1500	125	313	4750	1125
UNICELL. GREENS	2250	1375	2125	3000	2000	1625	4000	2438
BLUE-GREENS					4438	2125		

21.08.91
NO SAMPLES

30.08.91	1	5	6	7	10	11	12	13
PHYTOPLANKTON								
CRYPTOPHYCEAE	31	250	63					188
DIATOMS	282	188	63	1188	438	750	375	2625
COL. GREENS	1344	6750	3375	23250	6625	2188	9125	24625
UNICELL. GREENS	1000	1625	1750	3313	1688	3188	1000	1313
BLUE-GREENS			313					

05.09.91
NO SAMPLES

10.09.91	1	5	6	7	10	11	12	13
PHYTOPLANKTON								
CRYPTOPHYCEAE	125	188	563	750	500	63	63	563
DIATOMS	250	375	438	188	313	500	625	63
COL. GREENS	8563	7000	12313	6063	1750	4875	3500	1500
UNICELL. GREENS	2063	2375	4750	2063	1250	2875	625	1188
BLUE-GREENS								

17.09.91	1	5	6	7	10	11	12	13
PHYTOPLANKTON								
CRYPTOPHYCEAE	31	83	125	500	250	188		63
DIATOMS	63	126	250	438	438	1063	31	438
COL. GREENS	2688	1083	3625	10125	9313	8188	1813	3375
UNICELL. GREENS	375	250	938	4063	3813	4000	1063	2000
BLUE-GREENS								

25.09.91	1	5	6	7	10	11	12	13
PHYTOPLANKTON								
CRYPTOPHYCEAE	31	312	375	250	375	500		125
DIATOMS	219	250	437	63	687	500	375	687
COL. GREENS	1000	3375	8687	3063	8687	4125	8687	7125
UNICELL. GREENS	594	1875	2125	1937	1937	2750	1500	1687
BLUE-GREENS								1687

TABLE 3

ZOOPLANKTON OF GRAFHAM WATER

Rotifers:	*Asplanchna* sp
	Brachionus angularis
	Brachionus calyciflorus
	Brachionus rubens
	Keratella cochlearis
	Keratella quadrata
	Polyarthra sp
	Notholca squamula
Cladocera:	*Bosmina* sp
	Daphnia sp
	Ceriodaphnia sp
	Chydorus sp
Copepods:	Calanoid copepods
	Cyclopoid copepods
	Nauplii
Ostracods:	Ostracoda

TABLE 4

GRAFHAM WATER - SURVEY 1991
NUMBERS PER LITRE

23.5.91	1	5	6	7	10	11	12	1
ZOOPLANKTON								
ROTIFERS	201	68	82	116	29	44	60	
CLADOCERA	3	7		10	1	2	1	
COPEPODS	273	112	141	164	49	41	26	
OSTRACODS					1			

30.5.91	1	5	6	7	10	11	12	1
ZOOPLANKTON								
ROTIFERS	142	179	196	200	17		116	4
CLADOCERA	8	16	5	12			4	
COPEPODS	110	118	86	121	89	305	104	30

5.6.91	1	5	6	7	10	11	12	1
ZOOPLANKTON								
ROTIFERS	243	117	193	176	120	69	37	5
CLADOCERA	34	20	75	55			11	
COPEPODS	133	92	122	119	636	230	41	7

12.06.91
NO SAMPLES

21.6.91	1	5	6	7	10	11	12	1
ZOOPLANKTON								
ROTIFERS	96	163	143	312	40		20	3
CLADOCERA	120	337	200	1480	111	233	24	6
COPEPODS	173	200	133	296	193	2500	108	18

26.6.91	1	5	6	7	10	11	12	1
ZOOPLANKTON								
ROTIFERS	56	226	112	98	37	14	100	7
CLADOCERA	798	6228	342	253	389	160	6733	26
COPEPODS	70	158	126	84	80	196	200	12

3.7.91	1	5	6	7	10	11	12	1
ZOOPLANKTON								
ROTIFERS	27		67	147		13		6
CLADOCERA	594		1917	223	546	387	3120	132
COPEPODS	135		83	227	35	127	240	35

10.7.91	1	5	6	7	10	11	12	1
ZOOPLANKTON								
ROTIFERS	83	90	123	2	74	8	16	
CLADOCERA	25	53	100	31	42	50	49	1
COPEPODS	165	196	273	149	310	567	116	12

17.7.91	1	5	6	7	10	11	12	1
ZOOPLANKTON								
ROTIFERS	47	58	29	42	32	58	168	
CLADOCERA	19	120	21	35	13		37	
COPEPODS	303	281	271	483	152	433	971	7

22.7.91	1	5	6	7	10	11	12	1
ZOOPLANKTON								
ROTIFERS	23	120	78	113		17	10	8
CLADOCERA		13	3	23	33	17	5	1
COPEPODS	336	320	181	243	2100	2533	110	12

29.7.91	1	5	6	7	10	11	12	1
ZOOPLANKTON								
ROTIFERS	159	160	142	250	2	6	45	27
CLADOCERA	5	10	13	4		1	6	
COPEPODS	164	224	151	146	89	75	238	65
OSTRACODA							3	

07.08.91

NO SAMPLES

14.08.91
NO SAMPLES

21.08.91
NO SAMPLES

30.8.91	1	5	6	7	10	11	12	1[illegible]
ZOOPLANKTON								
ROTIFERS	23	61	156	307	25	6		[illegible]
CLADOCERA	21	111	116	138	190	4	35	2[illegible]
COPEPODS	67	219	276	128	63	24	260	37[illegible]
OSTRACODA	0	0	0	0	0	0	25	

04.09.91	1	5	6	7	10	11	12	13
ZOOPLANKTON								
ROTIFERS	59	42	61	257	136	69	82	
CLADOCERA	56	22	47	153	25	78	30	
COPEPODS	92	68	48	237	36	72	90	

10.09.91	1	5	6	7	10	11	12	[illegible]
ZOOPLANKTON								
ROTIFERS	3	12	19	8	42	7	14	[illegible]
CLADOCERA	1		5	25	3	2	1	1[illegible]
COPEPODS	29	23	43	17	56	87	59	[illegible]

17.09.91	1	5	6	7	10	11	12	[illegible]
ZOOPLANKTON								
ROTIFERS	22	15	35	11	10	8	5	
CLADOCERA								
COPEPODS	44	16	10	18	9	15	17	[illegible]

25.09.91	1	5	6	7	10	11	12
ZOOPLANKTON							
ROTIFERS	1		5	5	12	5	1
CLADOCERA	7			1	3	1	
COPEPODS	8	7	13	14	13	55	3

TABLE 5 GRAFHAM WATER - 1991
Numbers per square metre

23.5.91	2	3	4	5	6	7	8	9
CHIRONOMIDAE	1578	1267	1044	2156	1600	1311	1333	156
OLIGOCHAETA	311	911	911	1089	2244	1511	400	1200
LYMNAEA								
SPHAERIDAE				156				
VALVATIDAE								
CULICIDAE				67	22	44	22	22
HYDROBIIDAE								
NEMATODA								44
DREISSENIDAE								

26.6.91	2	3	4	5	6	7	8	9
CHIRONOMIDAE	756	378	444	956	756	956	1356	1133
OLIGOCHAETA	689	111	2222	667	1556	2222	2222	1556
LYMNAEA								
SPHAERIDAE								
VALVATIDAE								
CULICIDAE	22							
HYDROBIIDAE								
NEMATODA	22	22						
DREISSENIDAE								

22.7.91	2	3	4	5	6	7	8	9
CHIRONOMIDAE	867	400	600	1244	889	1289	867	1556
OLIGOCHAETA	578	422	600	667	556	844	1778	578
LYMNAEA								
SPHAERIDAE								
VALVATIDAE								
CULICIDAE	22			89	22		22	
HYDROBIIDAE								
NEMATODA	44		22	67	44	22	22	
DREISSENIDAE								44

30.8.91	2	3	4	5	6	7	8	9
CHIRONOMIDAE	400	156	111	444	156	244	556	378
OLIGOCHAETA	89		111	1867	178	1000	1644	1178
LYMNAEA								
SPHAERIDAE								
VALVATIDAE								
CULICIDAE	22	22		22				
HYDROBIIDAE								
NEMATODA					22			
DREISSENIDAE								

25.9.91	2	3	4	5	6	7	8	9
CHIRONOMIDAE	156			356	289	800	200	222
OLIGOCHAETA	667	400	733	622	911	2067	2333	1756
LYMNAEA			22					
SPHAERIDAE								
VALVATIDAE								
ERPOBDELLIDAE								
CULICIDAE								
HYDROBIIDAE								
NEMATODA								
DREISSENIDAE								

23.10.91	2	5	6	7	8	9	14	15	16
CHIRONOMIDAE	133	326	193	326	326	178		252	30
OLIGOCHAETA	578	1259	933	652	504	430	74	563	1081
LYMNAEA									
SPHAERIDAE									
VALVATIDAE									
ERPOBDELLIDAE									
CULICIDAE									
HYDROBIIDAE									
NEMATODA									
DREISSENIDAE									

25.11.91	2	5	6	7	8	9	14	15	16
CHIRONOMIDAE	1052	681	504	844	844	104		222	1126
OLIGOCHAETA	1689	1437	1793	3170	3630	385		2030	948
LYMNAEA									
SPHAERIDAE			15	30	15				15
VALVATIDAE									
ERPOBDELLIDAE									
CULICIDAE									
HYDROBIIDAE				30					
NEMATODA			74	15					59
DREISSENIDAE									

1990 DATA

Table 6.

GRAFHAM WATER - SURVEY 1990

CELLS PER MILLILITRE

26.7.90	1	5	6	7	10	11	12
PHYTOPLANKTON							
CRYPTOPHYCEAE	182	126	294	882	3192	669	546
DIATOMS		127	231	168	672	252	273
COL. GREENS	728	1554	1302	2520	2016	1218	1197
UNICELL. GREENS		42	147	378	420	168	147
BLUE-GREENS			84	1260	1680	105	

2.8.90	1	5	6	7	10	11	12
PHYTOPLANKTON							
CRYPTOPHYCEAE	1372	588	493	1400	273	74	1134
DIATOMS	112		102	28	126	294	168
COL. GREENS	1680	1960	935	1428	1218	2100	2310
UNICELL. GREENS	28	84				126	126
BLUE-GREENS		224					

9.8.90	1	5	6	7	10	11	12
PHYTOPLANKTON							
CRYPTOPHYCEAE	1596	1615	1020	224	NO	NO	NO
DIATOMS	42	85	85		SAMPLE	SAMPLE	SAMPLE
COL. GREENS	3738	5100	4930	2240			
UNICELL. GREENS	42	85	85				
BLUE-GREENS				560			

15.8.90	1	5	6	7	10	11	12
PHYTOPLANKTON							
CRYPTOPHYCEAE	765	425	850	340	252	NO	NO
DIATOMS	85	510	85	255	84	SAMPLE	SAMPLE
COL. GREENS	5610	6800	4675	4675	1540		
UNICELL. GREENS			85	85	170		
BLUE-GREENS	425	680	170		280		

22.8.90	1	5	6	7	10	11	12
PHYTOPLANKTON							
CRYPTOPHYCEAE	935	756	576	340	680	588	425
DIATOMS	340	168	42	255	255	210	255
COL. GREENS	4675	4116	3360	6800	4250	3570	4930
UNICELL. GREENS	85			85		42	85
BLUE-GREENS	4250	420	630		1700	1680	2550

28.8.90	1	5	6	7	10	11	12
PHYTOPLANKTON							
CRYPTOPHYCEAE	NO	NO	NO	680	NO	NO	NO
DIATOMS	SAMP	SAMPLE	SAMPLE	1105	SAMPLE	SAMPLE	SAMPLE
COL. GREENS				8075			
UNICELL. GREENS				85			
BLUE-GREENS				16150			

5.9.90	1	5	6	7	10	11	12
PHYTOPLANKTON							
CRYPTOPHYCEAE	336	255	NO	126	NO	NO	NO
DIATOMS	1554	2295	SAMPLE	1638	SAMPLE	SAMPLE	SAMPLE
COL. GREENS	2814	4420		2822			
UNICELL. GREENS	168	85		84			
BLUE-GREENS	420						

13.9.90	1	5	6	7	10	11	12
PHYTOPLANKTON							
CRYPTOPHYCEAE	84	168	672	756 →	NO	140	84
DIATOMS	546	588	462	714	SAMPLE	280	616
COL. GREENS	2688	3014	2730	2814		2548	2100
UNICELL. GREENS	84	126	126	126		84	224
BLUE-GREENS		420					

20.9.90	1	5	6	7	10	11	12
PHYTOPLANKTON							
CRYPTOPHYCEAE	210	252	84	252	42	63	NO
DIATOMS	1134	798	924	798	504	441	SAMPLE
COL. GREENS	2436	3402	2856	2226	2352	1134	
UNICELL. GREENS	42	126	84	84	84	189	
BLUE-GREENS							

27.9.90	1	5	6	7	10	11	12
PHYTOPLANKTON							
CRYPTOPHYCEAE	392	196	112	196	NO	NO	112
DIATOMS	56	224	112	140	SAMPLE	SAMPLE	56
COL. GREENS	1736	1372	1988	1960			1456
UNICELL. GREENS	84	84	84	56			28
BLUE-GREENS	250	420					

3.10.90	1	5	6	7	10	11	12
PHYTOPLANKTON							
CRYPTOPHYCEAE	112	84	42	126	168	NO	308
DIATOMS	112	252	714	294	504	SAMPLE	476
COL. GREENS	2100	2310	2940	3990	3948		1400
UNICELL. GREENS	56	42	42	42			56
BLUE-GREENS			630				

10.10.90	1	5	6	7	10	11	12
PHYTOPLANKTON							
CRYPTOPHYCEAE	728	462	504	644	NO	NO	252
DIATOMS	84	42	252	252	SAMPLE	SAMPLE	168
COL. GREENS	1456	2100	2898	1484			2016
UNICELL. GREENS	28	84	84	28			84
BLUE-GREENS							

16.10.90	1	5	6	7	10	11	12
PHYTOPLANKTON							
CRYPTOPHYCEAE	903	1008	420	336	NO	819	NO
DIATOMS	252	504	392	196	SAMPLE	273	SAMPLE
COL. GREENS	1113	1736	2128	1820		1134	
UNICELL. GREENS	42	28		28		21	
BLUE-GREENS			2660	280			

23.10.90	1	5	6	7	10	11	12
PHYTOPLANKTON							
CRYPTOPHYCEAE	196	672	448	567	NO	504	1176
DIATOMS	126	252	252	105	SAMPLE	224	546
COL. GREENS	700	2352	1400	1050		1456	2100
UNICELL. GREENS	28	84	28				
BLUE-GREENS				210			

Table 7.

GRAFHAM WATER - SURVEY 1990

NUMBERS PER LITRE

26.7.90	1	5	6	7	10	11	12
ZOOPLANKTON							
ROTIFERS	812	333	700	750	773	NO	NO
CLADOCERA	112	67	53	20	13	SAMPLE	SAMPLE
COPEPODS	401	340	400	420	1480		

2.8.90	1	5	6	7	10	11	12
ZOOPLANKTON							
ROTIFERS	80	120	64	20	15	32	72
CLADOCERA	12	13	43	43	8	5	4
COPEPODS	276	223	373	310	125	421	428

9.8.90	1	5	6	7	10	11	12
ZOOPLANKTON							
ROTIFERS	115	131	68	29	NO	NO	NO
CLADOCERA	15	29	20	3	SAMPLE	SAMPLE	SAMPLE
COPEPODS	245	181	212	131			

15.8.90	1	5	6	7	10	11	12
ZOOPLANKTON							
ROTIFERS	238	187	73	37	33	NO	NO
CLADOCERA	25	89	31	23	13	SAMPLE	SAMPLE
COPEPODS	324	342	373	207	447		

22.8.90	1	5	6	7	10	11	12
ZOOPLANKTON							
ROTIFERS	247	139	210	126	56	72	97
CLADOCERA	460	277	154	51		8	37
COPEPODS	553	293	406	345	289	260	217

29.8.90	1	5	6	7	10	11	12
ZOOPLANKTON							
ROTIFERS	1107	1632	NO	591	NO	NO	NO
CLADOCERA	280	48	SAMPLE	19	SAMPLE	SAMPLE	SAMPLE
COPEPODS	267	536		93			

5.9.90	1	5	6	7	10	11	12
ZOOPLANKTON							
ROTIFERS	460	185	NO	203	NO	NO	NO
CLADOCERA	157	65	SAMPLE	47	SAMPLE	SAMPLE	SAMPLE
COPEPODS	167	190		171			

13.9.90	1	5	6	7	10	11	12
ZOOPLANKTON							
ROTIFERS	58	237	565	833	198	181	176
CLADOCERA	20	13		27	11	10	5
COPEPODS	102	221	101	313	67	112	213

20.9.90	1	5	6	7	10	11	12
ZOOPLANKTON							
ROTIFERS	253	210	247	277	NO	527	NO
CLADOCERA	27	7	20	10	SAMPLE	10	SAMPLE
COPEPODS	380	257	283	287		483	

27.9.90	1	5	6	7	10	11	12
ZOOPLANKTON							
ROTIFERS	91	115	103	117	313	131	28
CLADOCERA	24	35	11	11		7	87
COPEPODS	248	205	245	299	140	231	44
OSTRACODA							3

3.10.90	1	5	6	7	10	11	12
ZOOPLANKTON							
ROTIFERS	89	58	74	43	72	NO	53
CLADOCERA	18	10	16	39	4	SAMPLE	827
COPEPODS	187	180	166	302	304		233
OSTRACODA	2						

10.10.90	1	5	6	7	10	11	12
ZOOPLANKTON							
ROTIFERS	77	81	37	44	57	NO	NO
CLADOCERA	8	13	6	8	1	SAMPLE	SAMPLE
COPEPODS	148	187	116	181	236		

16.10.90	1	5	6	7	10	11	12
ZOOPLANKTON							
ROTIFERS	77	32	68	85	107	NO	NO
CLADOCERA	23	8	40	17	3	SAMPLE	SAMPLE
COPEPODS	138	35	230	155	128		

23.10.90	1	5	6	7	10	11	12
ZOOPLANKTON							
ROTIFERS	102	102	88	96	50	34	28
CLADOCERA	62	27	38	23	5	3	4
COPEPODS	101	108	240	120	39	30	108

Table 8

GRAFHAM WATER - SURVEY 1990

NUMBERS PER m^2

26.7.90	2	3	4	5	6	7	8	9
CHIRONOMIDAE	1489	1378	1489	1533	1000	867	1111	844
OLIGOCHAETA	778	444	1111	2222	333	978	622	667
SPHAERIDAE				89				22
GLOSSIPHONIDAE				111				
NEMATODA	22		44		44			
DREISSENIDAE		22		244	22			

22.8.90	2	3	4	5	6	7	8	9
CHIRONOMIDAE	2044	933	1067	1444	778	711	578	733
OLIGOCHAETA	978	1333	1178	1222	1733	2511	2089	1422
SPHAERIDAE	22			111		22	22	
GLOSSIPHONIDAE		22		44				
NEMATODA		22		22				

20.9.90	2	3	4	5	6	7	8	9
CHIRONOMIDAE	600	956	622	622	622	1000	1156	1978
OLIGOCHAETA	3067	1422	911	1111	2178	1378	2044	1067
SPHAERIDAE	400	67	111	44	67	22		
VALVATIDAE		22	22	22		22		
ERPOBDELLIDAE			22		22			
CULICIDAE					22	22		

23.10.90	2	3	4	5	6	7	8	9
CHIRONOMIDAE	1644	2044	1511	1600	1289	2311	1489	2000
OLIGOCHAETA	4422	3644	5889	5444	2622	4422	2844	2000
SPHAERIDAE	44	44	89	89		44		44