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SEASONAL DATA ON THE MICROBIAL COMMUNITY OF FOUR NEW BRUNSWICK PONDS, INCLUDING A PERIOD OF EXPERIMENTAL SPRAYING WITH MATACIL®

by

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ABSTRACT

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Four ponds in New Brunswick were selected on the basis of similarities in physicochemical parameters and biological communities to test the effect of Matacil® on aquatic microbiology. Three ponds were sprayed in May 1980 with 140, 280 and 700 g Matacil® hectare^{-1}, respectively, and the fourth pond was a control. This report follows the seasonal microbiological cycle of these ponds from September 1979-September 1980. Even at 700 g ha^{-1}, Matacil® was found to have little effect on pond microbiology.

All the ponds exhibited the unusual phenomenon of a winter maximum in algal numbers during a period of ice cover.

Key words: Algae, bacteria, pesticides

RÉSUMÉ

Elner, J. K., and D. J. Wildish. 1981. Seasonal data on the microbial community of four New Brunswick ponds, including a period of experimental spraying with Matacil®. Can. Tech. Rep. Fish. Aquat. Sci. 993, iii + 21 p.

Nous avons vérifié les effets du Matacil® sur la faune microbienne de quatre étangs du Nouveau-Brunswick, choisis d'après leurs similarités physico-chimiques et biologiques. En mai 1980, trois de ces étangs étaient arrosés au Matacil®, à raison de 140, de 280 et de 700 g/ha, respectivement, le dernier servant de émoin. Nous avons contrôlé l'évolution microbiologique saisonnière de ces étangs de septembre 1979 à septembre 1980. Même à 700 g/ha, le pesticide a eu peu de répercussions.

Fait inhabituel, le nombre d'algues a atteint un maximum dans tous les étangs alors qu'ils étaient recouverts de glace.

INTRODUCTION

Freshwater ecosystems in forests depend on primary production and allochthonous organic matter utilized by heterotrophic microorganisms to support food webs leading to fish production. In New England, USA, and the Maritime Provinces of Canada, these fish provide a valuable sport and commercial fishery, notably of Atlantic salmon (*Salmo salar*, Linnaeus) and brook trout (*Salvelinus fontinalis*, Mitchill). A common forest culture practice in southeastern Canada and northeastern USA is the application of aerially sprayed pesticides to control the spruce budworm (*Choristoneura fumiferana*, Clemens) (Anon. 1975). One of the earliest forest pesticides used in New Brunswick was the chlorinated hydrocarbon, DDT, which was replaced in 1969, probably because of deleterious side effects found in the freshwater ecosystem (Dimond et al. 1968; Buhler 1969). The major pesticide used since is the organophosphate, fenitrothion, with the introduction in 1978 of the carbamate, aminocarb. The operational formulation used in New Brunswick consists of 21.7% aminocarb, 51.2% nonylphenol, and 27.1% "diesel-585" oil (McLeese et al. 1980).

An ecological study of freshwater microorganisms was initiated in 1979 to determine the field effects of simulated pesticide spraying. We know of no previous field studies involving the forest pesticide Matacil® in lentic habitats. The objectives were: (a) to assess changes caused by forest pesticides on the functioning of major physiological groups of freshwater microorganisms; (b) to determine the chemical fate of pesticides in the pond water and sediment. Component studies included seasonal and diurnal observations of a range of biological parameters in the study ponds.

This report presents the seasonal data for the period September 1979-September 1980, and includes the period of simulated operational spraying with Matacil®. One pond received 140 g ha^{-1}, the pesticide level expected to reach freshwater ecosystems from the operational spray program. Two other ponds were sprayed with two and five times this level, respectively. The diurnal study and pesticide analytical data will be published elsewhere.

METHODS

The four New Brunswick ponds chosen (Table 1) are similar in morphometry, bedrock, algal community and surrounding flora. The morphometry of each pond and the area of associated marshland were mapped (Fig. 1). The major morphometric features of each pond are indicated in Table 2.

Ponds A, C and D fall into a region of silurian rock formation. Rock types in this area include: greywacke, slate, siltstone, conglomerate, and limestone; minor ferruginous and manganiferous chert and argillite; minor volcanic rocks, interbedded mafic and silcic volcanic rocks. Pond B is situated in a Devonian formation, which consists of shale, limestone, sandstone, minor greywacke, tuff and volcanic rocks (Dept. of Natural Resources Geological Map No. N.R.-1, 1968).

The predominant macrophytes in the ponds and their catchment areas were surveyed.

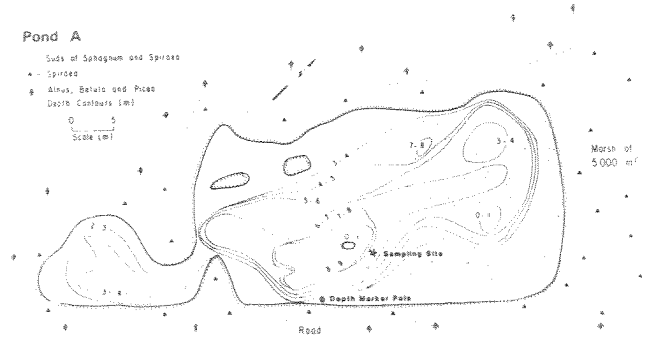
A monthly hydrograph was constructed from climatic data for the area by the method of Thornthwaite and Mather (1957). This technique

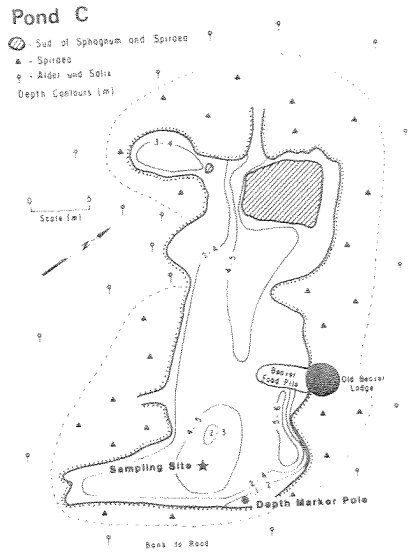
Table 1. Location of study ponds, pesticide dosage and date applied.

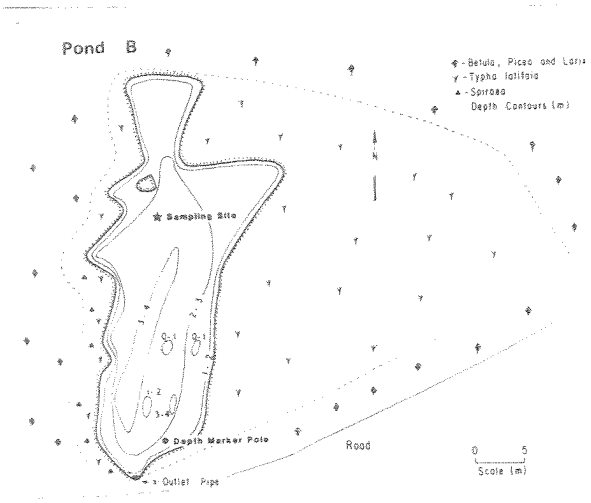
Pond	Grid reference	Sampling time	Matacil® treatment (g aminocarb ha^{-1})	Application date
A	45°15'50"N 67° 8'45"W	0830	0-control	
B	45° 8'12"N 67° 2'50"W	1015	140	27.05.80
C	45°16'30"N 67° 8'10"W	0900	700	03.06.80
D	45°16'45"N 67° 6'50"W	0930	280	29.05.80

Table 2. Morphometric features of study ponds. All depth values are for August 1979.

Pond	Catchment area (m^2)	Surface area pond (m^2)	Mean depth (m)	Max. depth (m)	Residual volume (m^3)	Surface area: volume ratio
A	5388	1060	0.41	0.92	305	3.47
B	878	410	0.23	0.38	76	5.40
C	430	391	0.32	0.64	109	3.59
D	997	382	0.33	0.60	110	3.45







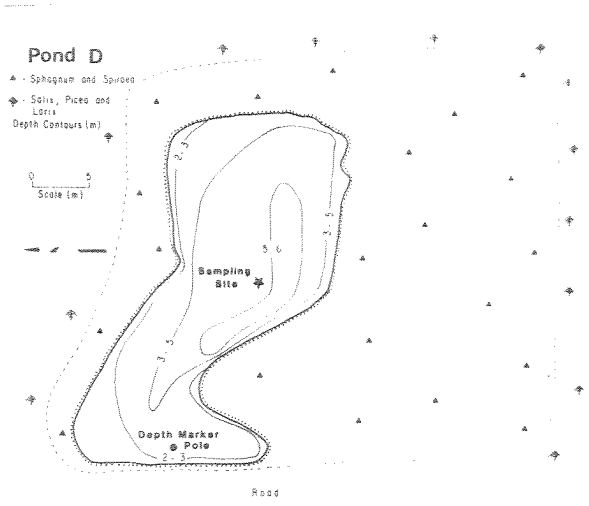


Fig. 1. Maps of the four study ponds showing depth contours in meters.

allows the calculation of precipitation available directly as runoff after corrections for actual evapotranspiration and lockup in ice and snow.

Matacil® was sprayed onto the ponds in a fine mist from a Solo 423 knapsack sprayer (Boynton and Smith 1971) in three treatments (Table 1). The pesticide was mixed with a full tank of water and remained in an emulsion during spraying. The sprayer nozzle was opened fully. Each application took place at 5:00 a.m. when the air was cold and damp so as to minimize drift of the pesticide. It was possible to spray the entire surface area of each pond from the banks.

SAMPLING PROCEDURES

Water samples were collected from each pond once or twice a month through the period from September 1979-September 1980. All sampling took place from permanent 'catwalks' so that the ponds remained undisturbed.

To avoid errors due to the mosaic nature of pond water, samples were taken from fixed sampling stations (Fig. 1) by using a 0.5 m^{-3} surface sampler. Water samples for analyses sensitive to the introduction of atmospheric oxygen were always removed first. Since diurnal variations in physical, chemical, and biological parameters were apparent, each pond was sampled at the same time of day (Table 1).

PHYSICAL PARAMETERS

Water depth in each pond was read from permanently positioned depth marker poles (Fig. 1). Temperature and Eh were measured directly at the standard sampling site in each pond with a mercury thermometer, and an Orion research ionanalyser (Model 407), equipped with a platinum redox electrode. A Radiometer 29 meter and combination probe was used to record pH in the laboratory to a precision of 0.05 pH units. Levels of dissolved oxygen were determined by the Winkler titration technique (Strickland and Parsons 1972) on three replicate samples from each pond. The concentration of dissolved organic matter in filtered pond water was measured directly on a Beckman Model 25 spectrophotometer at a wavelength of 250 nm with deionized water in the reference cell.

CHEMICAL PARAMETERS

Water samples (1 L) for pesticide analyses were obtained directly from the ponds in smoked glass bottles. Pesticide grade ethyl acetate (15 mL) was added to these samples to trap the Matacil® and metabolites. All samples were kept at 4°C in the dark until final extraction and analysis in the laboratories of the Research and Productivity Council, Fredericton, N.B. Matacil® and its metabolites were analyzed following the procedures described in Mallet (1978).

BIOLOGICAL PARAMETERS

Direct counts were made of predominant algal and invertebrate taxa. In each case, 40 mL of pond water was centrifuged and the supernatant discarded until all the algae had been concentrated to 1 mL. Of this, a 20 µL aliquot was counted by using a Zeiss photomicroscope and a x40 objective. Chlorophyll *a* was measured spectrophotometrically by the improved trichromatic method of Parsons and Strickland (1963). Chlorophyll *a* readings were corrected for the interference of phaeophytins (Moss 1967). This latter method also gives a value for total phaeophytin present. Carotenoid pigments were estimated by using the method of Strickland and Parsons (1972).

Direct counts of bacteria were made with a Zeiss epi-fluorescence microscope following the acridine orange technique described by Hobbie et al. (1979).

MICROBIAL ACTIVITY

Measurements of ATP were made by using the firefly bioluminescence assay method (Strehler and EcElroy 1957) with the use of an adapted Farrard fluorometer and a Brinkmann Servogor 5 fast response recorder (Wildish 1976).

Photoheterotrophic activity in phytoplankton was measured by the light and dark bottle technique described in Pentecost and Happey-Wood (1978), using $NaH^{14}CO_3$ as a tracer.

RESULTS

The water input into each pond has been calculated from a monthly hydrograph (Appendix 1) and is presented in Tables 3 and 4.

The predominant taxa growing in the vicinity of each pond and the major aquatic macrophytes are recorded in Table 5.

Matacil® occurred in concentrations up to 53 ppb in pond D 13 h after spraying and was still detectable to low levels, 0.9 ppb, 12 d later. Three metabolites were detected: 4-(formylamino)-3-methylphenol methyl carbamate, 4-amino-3-methylphenol, and 4-(methylamino)-3-methylphenol. Metabolites were found to persist for 24 d (after Matacil® application); 4-(formylamino)-3-methylphenol was not detected in any samples.

Water depth changes in the study ponds are recorded in Appendix 2. Records of temperature, Eh, and pH throughout the 12-mo period are presented in Appendix 3; those for dissolved oxygen and dissolved organic matter are recorded in Appendices 4 and 5, respectively. For 6 wk, from the end of January to the beginning of March, ponds B, C, and D froze down to the sediment, making water sampling impossible during this period. The plant pigment record for the study ponds is presented in Appendices 6-9. The major microscopic algae and invertebrates have been calculated as numbers per m^3 and are presented in Appendices 10-13. Bacterial counts in pond water were started in April 1980 and the results are shown in Appendix 14. Microbial activity in the water of the study ponds was measured as ATP content (Appendix 15). Algal primary production was assessed as the uptake of carbon per hour (Appendix 16).

DISCUSSION

The four ponds were similar in all physico-chemical and biological parameters assessed (Appendices 3-16) and, thus, formed an ideal system for these experimental studies. Since the ponds were small, it was possible to apply the pesticide evenly

Table 3. Input of water from precipitation directly onto the pond surface.

Pond \ Month	Water input (m^3) S	O	N	D	J	F	M	A	M	J	J	A	S	Total
A	137.8	265.0	137.8	42.4	58.3	55.6	153.7	143.1	153.7	53.3	79.5	34.4	145.7	1,460.3
B	53.3	102.5	53.3	16.4	22.5	21.5	59.4	55.3	59.4	22.5	30.7	13.3	56.3	566.4
C	50.8	97.7	50.8	15.6	21.5	20.5	56.6	52.7	56.6	21.5	29.3	12.7	53.7	540.0
D	49.6	95.5	49.6	15.2	21.0	20.0	55.3	51.5	55.3	21.0	28.6	12.4	52.5	527.5

Table 4. Input of water from catchment area.

Pond \ Month	Water input (m^3) S	O	N	D	J	F	M	A	M	J	J	A	S	Total
A	20.2	572.4	599.4	299.0	149.5	74.0	36.3	17.5	431.0	215.5	107.7	53.8	26.9	2,603.2
B	3.29	93.2	97.6	48.7	24.3	12.0	5.9	2.85	70.2	35.1	17.5	8.7	4.3	423.6
C	1.61	45.6	47.8	23.8	11.9	5.9	2.9	1.3	34.4	17.2	8.6	4.3	2.1	207.4
D	3.73	93.2	110.9	55.3	27.6	13.7	6.7	3.2	79.7	39.8	19.9	9.9	4.9	468.5

Table 5. Predominant plant taxa growing in and around the ponds.

Taxa	Pond A	Pond B	Pond C	Pond D
Trees:				
Abies balsamea	X			
Alnus	X		X	
Betula	X	X		
Larix		X		X
Picea	X	X		X
Salix	X	X	X	X
Shrubs:				
Spireae latifolia	X	X	X	X
Aquatic macrophytes:				
Calla palustris	X			
Juncus	X	X	X	X
Nuphar	X	X	X	X
Sagittaria cuneata			X	
Sphagnum	X	X		X
Typha latifolia		X		
Equisetum			X	

over the entire surface from the banks. This was important as it meant the surface microlayer remained undisturbed. While working with fenitrothion, Maguire (1980) found that volatization from the surface microlayer was very fast, with a half-life of 0.3 h. It is likely, however, that the microbial communities supported by such small systems will vary greatly from year to year. It is therefore important that these year-round, in-depth studies continue to provide a baseline from which to judge the effects of future pesticide applications.

Our studies indicate that Matacil® in the concentrations investigated had little effect on the microbial communities. All ponds experienced a normal spring bloom with comparable peaks in algal numbers shortly after the pesticide applications.

All the experimental ponds experienced high levels of chlorophyll (Appendices 6, 7) and algal counts (Appendices 10-13) during the winter months, December-February, when each pond was ice covered. Such winter maxima are unrecorded and have received little attention in the literature. The phenomenon was first noted by Harvey (1939), while working with the diatom *Ditylum brightwelli* (West) in the English Channel. He found that the organic material required for the growth of this diatom was present only during the winter. There is also evidence of increases of certain species of unicellular algae in small lakes and ponds under ice which produce extraordinarily large maxima (Hutchinson 1967). This suggests that, as in the marine situation, some freshwater species may be dependent upon some special chemical conditions which are most likely to be present during winter. Other recorded cases of winter maxima deal with increases in one particular species of algae in each pond: Burkholder (1931) found such maxima for the Chlorophyceae *Chlamydomonas angulosa* (Dill) and *Cartenia globosa* (Korschikoff), and the Dinophyceae *Glenodinium neglectum* (Schilling) and *Peridium inconspicuum* (Lemmarmann). Sze (1974), working on Lake Erie, found diatoms to be the dominant phytoplankter under ice. However, these diatoms were always at a minimum during the winter although, in recent years, the reduction has been less pronounced, an indication of increased eutrophication (Sze 1974). In comparison, winter maxima in our New Brunswick study ponds include desmids as well as a number of diatom and flagellate genera.

The winter of 1979-80 was relatively snow free, usually no more than a few centimeters of snowfall, which was always short-lived. It may be that in a year with heavy snowfall insufficient light penetration could curb the observed winter peaks. Wright (1964), working in lakes in eastern Massachusetts, found that a number of species of flagellates showed exponential increases to a maximum during January and February but that these declined rapidly after a series of snowfalls. Further studies are necessary to determine the long-term effects of annual applications of Matacil® and to investigate any future occurrence of winter algal maxima.

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Appendix 1. Water balance record based on climate data collected at the Biological Station, St. Andrews, N.B. This hydrograph was derived by the method of Thornthwaite and Mather (1957) and uses the same abbrebiations. It was necessary to report temperatures in °F in order to use the tables presented by Thornthwaite and Mather (1957).

	1979				1980								
Month	S	O	N	D	J	F	M	A	M	J	J	A	S
Mean T(°F)	54.5	47.4	41.9	26.9	23.3	23.1	31.6	43.0	52.1	60.2	65.1	63.6	59.3
I	4.0	2.26	1.16	0	0	0	0	1.35	3.38	5.64	7.18	6.69	5.37
Unadj.PE	0.09	0.06	0.02	0	0	0	0	0.05	0.07	0.10	0.12	0.12	0.10
PE(inch)	2.80	1.69	0.47	0	0	0	0	1.69	2.68	3.87	4.71	4.35	3.12
P	5.2	10	5.2	1.6	2.2	2.1	5.8	5.4	5.8	2.2	3.0	1.3	5.5
P-PE	2.4	8.3	4.7	1.6	2.2	2.1	5.8	3.7	3.2	-1.6	-1.7	-3	2.4
Acc.Pot.Wl										-1.6	-3.3	-6.3	
ST	9.82	12	12	22.5	32.4	42.4	49.7	8.81	12	10.50	9.11	7.09	9.82
ST	-2.73	0	0	0	0	0	0	-3.19	0	-1.5	+1.39	+2.02	-2.73
AE	2.80	1.69	0.47	0	0	0	0	1.69	2.68	3.7	4.39	3.32	3.12
D	0	0	0	0	0	0	0	0	0	0.17	0.32	1.03	0
S	0	8.3	4.7	0	0	0	0	0	3.2	0	0	0	0
RO	0.05	4.20	4.45	2.22	1.11	0.55	0.27	0.13	1.6	0.8	0.4	0.2	0.1
SmRO	0.1	0.05	0	0	0	0	0	0	1.6	0.8	0.4	0.2	0.1
TOTRO	0.15	4.25	4.45	2.22	1.11	0.55	0.27	0.13	3.2	1.6	0.8	0.4	0.2
DT	10.07	16.25	16.05	20.28	31.29	41.85	49.43	8.94	15.2	12.1	10.31	7.69	10.12

Appendix 2. Depth of water (cm) in each pond as recorded by the permanent depth poles (number in brackets represents the thickness of ice in cm).

Date	Pond A	Pond B	Pond C	Pond D
15.08.79	43	10	31	34.5
05.09.79	40	41	45	35.5
17.09.79	33	38	50	37
24.09.79	45	40	52	49.5
26.09.79	42	41	49	52
10.10.79	48	43	53.5	49
17.10.79	47	39	52	50
30.10.79	50	43	53	50
05.11.79	47	40	53	49.5
13.11.79	46	39	54	49.5
22.11.79	48	40	53	48
27.11.79	45.5	38.5	52	51
18.12.79	56 (12)	39 (10)	52 (9)	49 (8)
08.01.80	49 (30)	40 (40)	52 (30)	48 (30)
19.02.80	20 (45)	0 (50)	0 (50)	0 (50)
09.04.80	44	21	58	42
21.04.80	62	21	57	46
22.04.80	63	24	57	45
12.05.80	>70		56	46
20.05.80	48	23	53	45
09.06.80	48	18	43	44
11.06.80	50	24	47	44
17.06.80	48	18	46	43
25.06.80	44	15		
09.07.80	48	17	45	41
23.07.80	>70	23	38	44
06.08.80	>70	20	46	44
16.09.80	58	20	35	40

Appendix 3. Changes in temperature, pH and Eh from September 1979-September 1980 in the study ponds (pH - pH units; Eh - relative to NHE).

Date	Pond A			Pond B			Pond C			Pond D		
	Temp (°C)	pH	Eh	Temp (°C)	pH	Eh	Temp (°C)	pH	Eh	Temp (°C)	pH	Eh
05.09.79	8.7	6.3	271	10.5	6.0	267	8.2	6.2	266	10.3	5.3	271
26.09.79	11	6.05	268	15	5.8	270	11	6.05	267	13	5.35	271
10.10.79	6.5	5.8	270	6.5	5.5	278	6.2	5.6	270	6.5	5.2	273
20.10.79	6	6.45	274	6	6.2	280	6	6.5	280	6	5.85	284
05.11.79	4	6.4	275	4	6.5	277	4	6.3	278	4	5.75	284
13.11.79	3	5.6	272	3.5	5.3	280	3.8	5.5	279	4	4.8	279
22.11.79	1.5	6.2		3.1	6.0		2.5	6.15		3.2	5.35	
27.11.79	8	6.1	277	8	5.85	280	8	6.0	278	6	5.35	281
18.12.79	0	5.5	272	0	5.4	276	0	5.6	272	0	5.0	279
08.01.80	0	5.5	269	0	5.25	276	0	5.75	275	0	5.1	279
21.01.80	0	5.75	276	0	5.3	267	0	5.8	269	0	5.25	265
19.02.80	0	6.2	255									
18.03.80	0	4.9	281							0	5.4	278
09.04.80	1	5.75		2.3	5.5		2	5.70		5	5.25	
21.04.80	5			5			6			9		
22.04.80	0.5	5.4	275	0.5	5.8	279	5	6.0	275	7	5.6	279
12.05.80	13	6.0	274	14	5.3	259	13	5.9	273	15	4.6	233
20.05.80	10	5.9	273	15	5.5	229	14	5.85	234	15	5.2	267
09.06.80	9		261	9		267	10		266	12		267
11.06.80	9		265	14			12		282	14		
20.06.80	13		262	15		264	13		263	18		265
25.06.80	19		274	11		269	18		269	21		269
09.07.80	14		265	20		268	15		263	14		269
23.07.80	17	5.7	263	15	5.45	269	17	5.75	259	19	5.2	265
06.08.80	13	5.5	265	14	5.45	269	18	5.7	265	20	5.4	266
19.09.80	9	5.8	269	10	5.4	266	9.5	6	261	9	4.9	266

Appendix 4. Changes in dissolved oxygen from September 1979-September 1980 in the study ponds.

Date	Dissolved oxygen (gm^{-3}) ± S.E.			
	Pond A	Pond B	Pond C	Pond D
05.09.79	4.56 ± 0.07	4.76 ± 0.07	1.78 ± 0.07	7.27 ± 0.08
17.09.79	4.33 ± 0.00	4.87 ± 0.07	3.32 ± 0.07	4.17 ± 0.08
24.09.79	4.33 ± 0.00	5.88 ± 0.00	4.64 ± 0.17	4.74 ± 0.07
10.10.79	0.77 ± 0.08	9.59 ± 0.18	6.19 ± 0.35	4.12 ± 0.10
30.10.79	4.43 ± 0.10	8.15 ± 0.10	9.29 ± 0.00	9.08 ± 0.10
13.11.79	6.50 ± 0.00	8.51 ± 0.10	9.59 ± 0.00	6.81 ± 0.07
27.11.79	8.05 ± 0.10	8.05 ± 0.14	8.36 ± 0.05	6.81 ± 0.00
18.11.79	8.51 ± 0.15	8.97 ± 0.17	8.04 ± 0.00	5.57 ± 0.00
08.01.80	1.54 ± 0.00	6.03 ± 0.15	7.27 ± 0.15	2.16 ± 0.00
21.01.80	3.09 ± 0.03	5.41 ± 0.12	6.19 ± 0.10	6.03 ± 0.03
19.02.80	0.00 ± 0.00			
18.03.80	8.66 ± 0.00			3.09 ± 0.00
09.04.80	10.22 ± 0.29	10.71 ± 0.11	8.49 ± 0.15	6.84 ± 0.14
22.04.80	11.27 ± 0.24	6.91 ± 0.45	8.42 ± 0.68	7.89 ± 0.15
12.05.80	6.27 ± 0.19	4.34 ± 0.45	6.34 ± 0.15	6.87 ± 0.44
20.05.80	7.95 ± 0.14	7.10 ± 0.73	6.23 ± 0.12	4.32 ± 0.15
09.06.80	5.07 ± 0.26	7.06 ± 0.23	4.18 ± 0.13	1.78 ± 0.65
11.06.80	6.10 ± 0.40	3.27 ± 0.03	6.16 ± 0.18	4.31 ± 0.32
17.06.80	1.88 ± 0.01	2.16 ± 0.01	1.74 ± 0.01	1.70 ± 0.06
25.06.80	2.42 ± 0.23	4.59 ± 0.69	3.93 ± 0.81	3.03 ± 1.82
09.07.80	4.01 ± 0.42	4.26 ± 0.97	2.76 ± 0.10	4.31 ± 0.32
23.07.80	2.22 ± 0.05	2.06 ± 0.17	1.09 ± 0.06	0.62 ± 0.04
06.08.80	1.54 ± 0.13	2.93 ± 0.05	1.04 ± 0.12	2.17 ± 0.48
16.09.80	6.17 ± 0.19	4.53 ± 0.44	3.73 ± 0.09	4.53 ± 0.24

Appendix 5. Changes in dissolved organic matter from September 1979-September 1980 in the study ponds.

Date	Dissolved organic matter as measured at 250 nm ± S.E.			
	Pond A	Pond B	Pond C	Pond D
05.09.79	0.88 ± 0.003	0.56 ± 0.001	0.84 ± 0.005	0.64 ± 0.004
17.09.79	0.94 ± 0.003	0.41 ± 0.003	0.82 ± 0.001	1.08 ± 0.007
24.09.79	0.87 ± 0.01	0.37 ± 0.021	0.75 ± 0.003	1.10 ± 0.013
26.09.79	0.75 ± 0.01	0.36 ± 0.003	0.65 ± 0.01	1.04 ± 0.004
10.10.79	0.70 ± 0.003	0.34 ± 0.017	0.69 ± 0.001	0.83 ± 0.009
30.10.79	0.48 ± 0.002	0.34 ± 0.004	0.57 ± 0.001	0.55 ± 0.006
13.11.79	0.44 ± 0.006	0.21 ± 0.04	0.48 ± 0.002	0.35 ± 0.003
22.11.79	0.28 ± 0.001	0.19 ± 0.004	0.33 ± 0.002	0.32 ± 0.001
27.11.79	0.42 ± 0.005	0.27 ± 0.002	0.42 ± 0.001	0.38 ± 0.004
18.12.79	0.42 ± 0.001	0.21 ± 0.006	0.37 ± 0.002	0.41 ± 0.003
08.01.80	0.38 ± 0.001	0.21 ± 0.006	0.33 ± 0.001	0.73 ± 0.004
21.01.80	0.36 ± 0.002	0.16 ± 0.006	0.32 ± 0.001	0.54 ± 0.007
19.02.80	0.08 ± 0.004			
18.03.80	0.07 ± 0.001			0.05 ± 0.001
09.04.80	0.32 ± 0.002	0.16 ± 0.00	0.31 ± 0.001	0.14 ± 0.002
22.04.80	0.32 ± 0.003	0.18 ± 0.001	0.29 ± 0.001	0.19 ± 0.004
12.05.80	0.36 ± 0.007	0.24 ± 0.001	0.32 ± 0.002	0.29 ± 0.001
20.05.80	0.44 ± 0.00	0.28 ± 0.001	0.41 ± 0.002	0.39 ± 0.00
17.06.80	0.50 ± 0.06	0.48 ± 0.06	0.52 ± 0.008	0.55 ± 0.00
09.07.80	0.63 ± 0.06	0.54 ± 0.16	0.55 ± 0.02	0.57 ± 0.02
23.07.80	0.03 ± 0.02	0.24 ± 0.013	0.55 ± 0.002	0.35 ± 0.009
06.08.80	0.91 ± 0.01	0.43 ± 0.015	0.79 ± 0.016	0.63 ± 0.005
16.09.80	0.74 ± 0.006	0.21 ± 0.005	0.44 ± 0.008	0.23 ± 0.008

Appendix 6. Changes in chlorophyll a from September 1979-September 1980 in the study ponds (determined by Parsons and Strickland method).

Date	Chlorophyll a ($g\ m^{-3}$) ± S.E.			
	Pond A	Pond B	Pond C	Pond D
05.09.79	0.429 ± 0.027	0.407 ± 0.058	0.340 ± 0.077	0.325 ± 0.045
17.09.79	0.350 ± 0.049	0.133 ± 0.017	0.271 ± 0.040	0.293 ± 0.002
24.09.79	0.361 ± 0.041	0.091 ± 0.029	0.176 ± 0.040	0.212 ± 0.03
26.09.79	0.223 ± 0.07	0.062 ± 0.071	0.259 ± 0.012	0.807 ± 0.023
10.10.79	0.325 ± 0.045	0.017 ± 0.021	0.117 ± 0.02	0.249 ± 0.03
30.10.79	0.268 ± 0.026	0.063 ± 0.006	0.110 ± 0.017	0.319 ± 0.004
13.11.79	0.174 ± 0.017	0.054 ± 0.002	0.095 ± 0.010	0.102 ± 0.004
27.11.79	0.198 ± 0.023	0.087 ± 0.001	0.135 ± 0.014	0.328 ± 0.038
18.12.79	0.198 ± 0.037	0.555 ± 0.09	0.195 ± 0.036	1.033 ± 0.084
08.01.80	0.702 ± 0.07	7.124 ± 0.95	1.024 ± 0.27	0.308 ± 0.04
21.01.80	0.436 ± 0.03	0.506 ± 0.07	1.61 ± 0.015	0.208 ± 0.03
19.02.80	4.90 ± 0.102			
18.03.80	0.26 ± 0.01			0.475 ± 0.03
10.04.80	0.109 ± 0.02	0.166 ± 0.04	0.315 ± 0.08	0.288 ± 0.036
22.04.80	0.083 ± 0.002	0.038 ± 0.008	0.146 ± 0.014	0.353 ± 0.007
12.05.80	0.214 ± 0.021	0.084 ± 0.004	0.196 ± 0.037	0.219 ± 0.015
20.05.80	0.126 ± 0.018	0.194 ± 0.014	0.198 ± 0.082	0.384 ± 0.096
09.06.80	0.403 ± 0.06	0.364 ± 0.05	0.523 ± 0.03	0.311 ± 0.04
11.06.80	0.221 ± 0.02	0.558 ± 0.10	0.574 ± 0.14	0.537 ± 0.03
17.06.80	0.327 ± 0.07	0.220 ± 0.02	0.458 ± 0.09	0.634 ± 0.08
25.06.80	0.508 ± 0.07	1.699 ± 0.09	0.901 ± 0.17	1.023 ± 0.26
09.07.80	0.548 ± 0.01	0.427 ± 0.05	0.360 ± 0.09	0.692 ± 0.06
23.07.80	0.533 ± 0.05		0.680 ± 0.09	4.78 ± 0.16
06.08.80	0.197 ± 0.017	0.352 ± 0.022	0.088 ± 0.013	0.129 ± 0.011
16.09.80	0.216 ± 0.064	0.226 ± 0.027	0.460 ± 0.015	0.243 ± 0.048

Appendix 7. Changes in the values of chlorophyll a after correction for phaeophytins from September 1979-September 1980 in the study ponds (determined by the technique of Moss 1967).

Date	Chlorophyll a ($g\ m^{-3}$) ± S.E.			
	Pond A	Pond B	Pond C	Pond D
17.09.79	0.02 ± 0.04	0.08 ± 0.16	0.17 ± 0.02	0.21 ± 0.003
24.09.79	0.34 ± 0.08	0.05 ± 0.02	0.12 ± 0.03	0.10 ± 0.009
26.09.79	0.16 ± 0.012	0.03 ± 0.02	0.11 ± 0.02	0.59 ± 0.01
10.10.79	0.20 ± 0.02	0.006 ± 0.01	0.07 ± 0.01	0.15 ± 0.02
30.10.79	0.181 ± 0.02	0.029 ± 0.005	0.069 ± 0.005	0.229 ± 0.007
13.11.79	0.081 ± 0.01	0.031 ± 0.002	0.041 ± 0.001	0.065 ± 0.003
27.11.79	0.102 ± 0.005	0.047 ± 0.001	0.063 ± 0.007	0.242 ± 0.034
18.12.79	0.104 ± 0.002	0.261 ± 0.001	0.079 ± 0.001	0.534 ± 0.003
08.01.80	0.376 ± 0.07	2.744 ± 0.279	0.540 ± 0.024	0.195 ± 0.037
21.01.80	0.305 ± 0.039	0.414 ± 0.075	0.09 ± 0.009	0.114 ± 0.002
19.02.80	0.362 ± 0.040			
18.03.80	1.770 ± 0.061			1.35 ± 0.071
10.04.80	0.043 ± 0.007	0.146 ± 0.024	0.096 ± 0.018	0.104 ± 0.021
21.04.80	0.030 ± 0.004	0.024 ± 0.004	0.077 ± 0.008	0.176 ± 0.016
12.05.80	0.118 ± 0.008	0.045 ± 0.003	0.094 ± 0.001	0.126 ± 0.009
20.05.80	0.07 ± 0.015	0.972 ± 0.007	0.068 ± 0.032	0.235 ± 0.051
09.06.80	0.124 ± 0.05	0.205 ± 0.02	0.240 ± 0.09	0.151 ± 0.05
11.06.80	0.777 ± 0.02	0.256 ± 0.01	0.234 ± 0.03	0.181 ± 0.04
17.06.80	0.163 ± 0.05	0.099 ± 0.001	0.294 ± 0.06	0.391 ± 0.05
25.06.80	0.167 ± 0.10	1.566 ± 0.28	0.463 ± 0.13	0.543 ± 0.18
09.07.80	0.284 ± 0.02	0.175 ± 0.02	0.152 ± 0.06	0.408 ± 0.02
23.07.80	0.249 ± 0.07	0.367 ± 0.22	0.396 ± 0.08	3.458 ± 0.11
06.08.80	0.276 ± 0.02	0.393 ± 0.031	0.189 ± 0.07	0.537 ± 0.09
16.09.80	0.910 ± 0.013	0.104 ± 0.020	0.205 ± 0.031	0.087 ± 0.012

Appendix 8. Changes in phaeophytin from September 1979-September 1980 in the study ponds.

Date	Phaeophytin ($g\ m^{-3}$) ± S.E.			
	Pond A	Pond B	Pond C	Pond D
17.09.79	0.13 ± 0.029	0.06 ± 0.01	0.07 ± 0.008	0.09 ± 0.005
24.09.79	0.19 ± 0.08	0.04 ± 0.01	0.07 ± 0.017	0.12 ± 0.031
26.09.79	0.135 ± 0.009	0.038 ± 0.01	0.140 ± 0.02	0.245 ± 0.029
10.10.79	0.173 ± 0.024	0.01 ± 0.009	0.065 ± 0.014	0.152 ± 0.018
30.10.79	0.120 ± 0.01	0.027 ± 0.002	0.056 ± 0.012	0.135 ± 0.005
13.11.79	0.107 ± 0.008	0.025 ± 0.003	0.049 ± 0.007	0.058 ± 0.003
27.11.79	0.102 ± 0.016	0.036 ± 0.003	0.061 ± 0.007	0.134 ± 0.006
18.12.79	0.092 ± 0.013	0.246 ± 0.010	0.069 ± 0.009	0.512 ± 0.013
08.01.80	0.350 ± 0.049	5.07 ± 0.674	0.656 ± 0.096	0.168 ± 0.025
21.01.80	0.180 ± 0.006	0.349 ± 0.074	0.060 ± 0.006	0.086 ± 0.001
19.02.80	0.436 ± 0.051			
18.03.80	1.94 ± 0.006			0.267 ± 0.620
10.04.80	0.064 ± 0.008	0.120 ± 0.015	0.113 ± 0.004	0.182 ± 0.032
21.04.80	0.045 ± 0.001	0.026 ± 0.005	0.079 ± 0.008	0.205 ± 0.013
12.05.80	0.116 ± 0.028	0.062 ± 0.002	0.116 ± 0.047	0.172 ± 0.012
20.05.80	0.097 ± 0.014	0.136 ± 0.010	0.135 ± 0.05	0.270 ± 0.081
09.06.80	0.327 ± 0.06	0.247 ± 0.06	0.443 ± 0.10	0.242 ± 0.005
11.06.80	0.170 ± 0.02	0.348 ± 0.02	0.325 ± 0.08	0.382 ± 0.02
17.06.80	0.273 ± 0.06	0.184 ± 0.02	0.241 ± 0.000	0.397 ± 0.06
25.06.80	0.386 ± 0.05	1.187 ± 0.01	0.548 ± 0.09	0.678 ± 0.19
09.07.80	0.397 ± 0.01	0.351 ± 0.04	0.264 ± 0.07	0.449 ± 0.05
23.07.80	0.405 ± 0.01	0.225 ± 0.05	0.445 ± 0.06	0.204 ± 0.09
06.08.80	0.585 ± 0.03	0.513 ± 0.020	0.387 ± 0.03	0.775 ± 0.163
16.09.80	0.156 ± 0.04	0.160 ± 0.011	0.337 ± 0.02	0.181 ± 0.033

Appendix 9. Changes in carotenoids from September 1979-September 1980 in the study ponds.

Date	Carotenoids ($g\ m^{-3}$) ± S.E.			
	Pond A	Pond B	Pond C	Pond D
17.09.79	0.163 ± 0.04	0.07 ± 0.002	0.19 ± 0.07	0.14 ± 0.028
24.09.79	0.04 ± 0.04	0.08 ± 0.00	0.08 ± 0.04	0.20 ± 0.03
26.09.79	0.09 ± 0.02	0.06 ± 0.00	0.35 ± 0.13	0.53 ± 0.02
10.10.79	0.197 ± 0.04	0.007 ± 0.02	0.042 ± 0.018	0.28 ± 0.04
30.10.79	0.085 ± 0.002	0.022 ± 0.003	0.10 ± 0.000	0.149 ± 0.038
13.11.79	0.057 ± 0.015	0.008 ± 0.001	0.054 ± 0.002	0.047 ± 0.008
27.11.79	0.080 ± 0.002	0.036 ± 0.004	0.108 ± 0.062	0.133 ± 0.031
18.12.79	0.042 ± 0.018	0.165 ± 0.004	0.064 ± 0.008	0.000
08.01.80	0.273 ± 0.088	3.016 ± 0.531	0.417 ± 0.005	0.341 ± 0.079
21.01.80	0.220 ± 0.089	0.305 ± 0.103	0.091 ± 0.009	0.203 ± 0.091
19.02.80	7.97 ± 0.981			
18.03.80	0.22 ± 0.02			0.30 ± 0.08
10.04.80	0.266 ± 0.001	0.068 ± 0.046	0.168 ± 0.008	0.334 ± 0.093
21.04.80	0.041 ± 0.011	0.033 ± 0.023	0.076 ± 0.012	0.250 ± 0.025
12.05.80	0.124 ± 0.014	0.063 ± 0.00	0.112 ± 0.032	0.260 ± 0.065
20.05.80	0.186 ± 0.07	0.327 ± 0.094	0.210 ± 0.102	0.342 ± 0.126
09.06.80	0.281 ± 0.130	0.167 ± 0.02	0.316 ± 0.008	0.219 ± 0.05
11.06.80	0.157 ± 0.03	0.352 ± 0.04	0.295 ± 0.08	0.494 ± 0.001
17.06.80	0.165 ± 0.006	0.146 ± 0.01	0.208 ± 0.09	0.490 ± 0.05
25.06.80	0.301 ± 0.08	1.080 ± 0.03	1.152 ± 0.27	0.860 ± 0.34
09.07.80	0.354 ± 0.02	0.503 ± 0.23	0.318 ± 0.07	0.571 ± 0.05
23.07.80	0.446 ± 0.07	0.314 ± 0.07	0.554 ± 0.07	2.933 ± 0.171
06.08.80	0.595 ± 0.016	0.416 ± 0.008	0.642 ± 0.042	1.01 ± 0.194
16.09.80	0.280 ± 0.044	0.219 ± 0.021	0.373 ± 0.021	0.269 ± 0.065

Appendix 10. Taxa of microalgae and invertebrates from Pond A (organism x 10^6 m^{-3}).

Taxa \ Date	05.09.79	17.09.79	10.10.79	30.10.79	13.11.79	27.11.79	18.12.79	08.01.80	21.01.80	19.02.80
Total chlorophyceae	247.9	214.1	142.4	182	97.7	75.0	73.7	125.0	270.0	1053.7
Filamentos "	2.6	19.1	7.4	18	7.5	13.7			28.7	18.75
Flagellate "	241.4	188.3	133.3	142	86.2	72.5	56.2	122.5	92.5	1012.4
Colonial "	1.3	1.6				11.2				
Pediastrum	1.3	0.8								
Scenedesmus	1.3									
Ehtreptia										848.7
Total diatoms	7.8	11.6		24	12.5	10.0	5.0	7.5	5.0	30.0
Total centrales		0.8								
Total pennales	7.8	10.8		24	12.5	10.0	5.0	7.5	5.0	30.0
Cyclotella										
Melosira										
Tabellaria floculosa								2.5		
T. floculosa (long)								2.5		1.2
Diatoma										
Meridion										
Fragilaria										
Asterionella formosa										
Synedra										
Eunotia										
Frustulia										
Navicula										
Pinnularia										
P. major										
Gomphonema										
Nitzchia										
Total desmids	1.3	8.3	0.8					45.0	6.2	36.2
Cosmarium	1.3							45.0	6.2	30.0
Closterium										6.2
Total chrysophyceae		0.8	0.8	2					2.5	
Dinobryon		0.8	0.8	2					2.5	
Total bluegreens	233.6	15.8	15.8	86	23.7	17.5	3.75	340	100	91.2
Nematodes	224.4	13.3	4.9	8	70.0	56.2	2.5	75.0	52.5	6.2
Rotifers				2						2.5
Ciliates		1.6	0.8				1.25			
Crustaceans	3.9									
X	169.6	0.8	2.4	36	36.2			60	27.5	22.5

Appendix 10 (cont'd).

Taxa \ Date	25.03.80	09.04.80	22.04.80	12.05.80	20.05.80	17.06.80	25.06.80	09.07.80	23.07.80	06.08.80	16.09.80
Total chlorophyceae	39.9	227.5	20.0	41.2	110.0	11.2	60.0	12.5	8.7	21.2	18.75
Filamentos "	13.7	15.0	3.7	2.5	5.0	5.0	18.7	7.5	8.7	2.5	5.0
Flagellate "	26.2	212.0	11.25	32.5	95.0	3.7	36.2	1.2		15.0	12.5
Colonial "											1.2
Pediastrum											
Scenedesmus											
Ehtreptia											
Total diatoms	21.2		8.75	16.2	10.0	15.0		36.2	8.7	52.5	7.5
Total centrales										1.2	
Total pennales	21.2		6.25	16.2	10.0	15.0		36.2	8.7	51.2	7.5
Cyclotella											
Melosira										1.2	
Tabellaria floculosa				3.7				5.0	5.0	3.7	
T. floculosa (long)	2.5							6.2		8.7	
Diatoma											
Meridion				1.2						5.0	
Fragilaria											
Asterionella formosa			2.5	2.5		3.7					
Synedra				1.2						1.2	
Eunotia	1.2				1.2	3.7		3.7	2.5	7.5	
Frustulia											
Navicula						5.0				13.7	5.0
Pinnularia											
P. major											
Gomphonema					1.2	1.2		2.5		1.2	
Nitzchia											
Total desmids	6.2	33.7					2.5				2.5
Cosmarium		33.7									
Closterium											
Total chrysophyceae				6.2						2.5	
Dinobryon				6.2						2.5	
Total bluegreens	18.7	36.2			6.2	5.0	15.0	8.7	381.2	3.7	8.75
Nematodes											
Rotifers				5.0	32.5	18.7	78.7	7.5			
Ciliates								2.5			
Crustaceans							1.2				
X							1.2				

Appendix 11. Major taxa of microalgae and invertebrates from Pond B (organism x 16^6 m^{-3}).

Taxa \ Date	05.09.79	17.09.79	10.10.79	30.10.79	13.11.79	27.11.79	18.12.79	08.01.80	21.01.80	09.04.80
Total chlorophyceae	46.6	100.8	35.9	5.6	26.2	15.0	146.2	740.0	41.6	92.5
Filamentos "	17.7	0.8	1.9	1.2		6.25	5.0	75.0	2.7	23.7
Flagellate "	16.5	94.1	31.9	3.6	26.2	8.75	117.5	415.0	36.8	62.5
Colonial "	0.3	0.8								
Pediastrum	2.7							15.0		
Scenedesmus	1.2	0.8								
Ehtreptia										848.7
Total diatoms	3.3	2.4	2.9		6.2	2.5	162.5	1380.0	140.2	70.0
Total centrales	0.3	1.6					10.0	105.0	19.4	
Total pennales	3.0	0.8	2.9		6.2	2.5	152.5	1275.0	120.8	70.0
Cyclotella							8.75			
Melosira								105.0	19.4	
Tabellaria floculosa							43.5	160.0	36.8	6.2
T. floculosa (long)								150.0	8.3	
Diatoma										
Meridion										
Fragilaria										
Asterionella formosa										
Synedra								100.0		3.7
Eunotia							6.25	100.0	14.5	13.7
Frustulia									9.0	
Navicula							35.0	210.0	13.2	3.7
Pinnularia							3.75	100.0		
P. major								30	5.4	
Gomphonema										
Nitzchia										
Total desmids	0.6	2.4					7.5	35.0		1.2
Cosmarium										1.2
Closterium										6.2
Total chrysophyceae		0.8	0.8	2					2.5	
Dinobryon		0.8	0.8	2					2.5	
Total bluegreens	7.9	4.1	7.9	1.6	6.2	10.0	13.7	355.0	13.8	30.0
Nematodes	26.9	3.4	2.4		5.0	3.7				
Rotifers								15.0		
Ciliates	1.8	1.6		2.0						
Crustaceans	3.0									
X	7.0		0.4						9	

Appendix 11. (cont.d)

Taxa \ Date	22.04.80	12.05.80	20.05.80	17.06.80	25.06.80	09.07.80	06.08.80	16.09.80
Total chlorophyceae	10.0	8.7	17.5	267.5	11.2	93.7	97.5	
Filamentos "			1.2		8.7	3.7	77.5	
Flagellate "	8.75	8.7	2.5	255.0		86.25	15.0	
Colonial "				11.2				
Pediastrum								
Scenedesmus								
Ehtreptia								
Total diatoms	3.7	26.2	3.7		6.2		53.7	1.2
Total centrales								
Total pennales	3.7	26.2	3.7		6.2		53.7	1.2
Cyclotella								
Melosira								
Tabellaria floculosa		17.5			2.5		25.0	
T. floculosa (long)			1.2					
Diatoma								
Meridion								
Fragilaria								
Asterionella formosa		3.7						
Synedra								
Eunotia	1.2						6.2	
Frustulia							1.2	
Navicula							3.7	
Pinnularia								1.2
P. major								
Gomphonema	1.2		2.5					
Nitzchia								
Total desmids					11.2		23.7	
Cosmarium								
Closterium								
Total chrysophyceae								
Dinobryon								
Total bluegreens	3.7		1.2					21.2
Nematodes		8.7						
Rotifers								
Ciliates								
Crustaceans								
X							1.2	

Appendix 12. Major taxa of microalgae and invertebrates from Pond C (organism x 10^6 m^{-3}).

Taxa \ Date	05.09.79	17.09.79	10.10.79	30.10.79	13.11.79	27.11.79	18.12.79	08.01.80	21.01.80	09.04.80
Total chlorophyceae	157.0	64.1	76.6	23.8	70.5	78.7	62.5	107.2	21.5	98.7
Filamentos "	22.6	3.3	1.6	2.7		11.2		4.8	4.1	5.0
Flagellate "	122.1	53.3	72.9	14.9	58.5	61.2	50.0	91.0	11.1	93.7
Colonial "	12.2					3.7				
Pediastrum				0.5						
Scenedesmus										
Ehtreptia										
Total diatoms	29.6	42.4	1.6	7.7	4.5	3.7	11.2	247.0	18.7	8.7
Total centrales		23.3	0.8	7.7					9.0	
Total pennales	29.6	19.1	0.8		4.5	3.7	11.2	247.0	9.7	8.7
Cyclotella									9.0	
Melosira								97.5	2.0	
Tabellaria floculosa										
T. floculosa (long)										
Diatoma								1.6		
Meridion										
Fragilaria										
Asterionella formosa								6.5		
Synedra								8.1		3.7
Eunotia										
Frustulia								13		
Navicula									0.6	
Pinnularia								8.1	2.0	
P. major								4.8		
Gomphonema										
Nitzchia										
Total desmids		0.8						4.8		23.7
Cosmarium										
Closterium										
Total chrysophyceae				0.5					0.6	8.7
Dinobryon				0.5					0.6	8.7
Total bluegreens	54.1	49.1	14.1	8.8	13.5	21.2	5	147.8	21.5	21.2
Nematodes	628.3	268.3	18.7	1.1	39.3	13.7	5	56.8	17.3	
Rotifers										
Ciliates		2.49	0.4	1.1						
Crustaceans										
X	109.9	26.6	0.8	1.1	7.5			84.5	2.7	

Appendix 12 (cont'd).

Taxa \ Date	22.04.80	12.05.80	20.05.80	17.06.80	25.06.80	09.07.80	23.07.80	06.08.80	16.09.80
Total chlorophyceae	50.2	16.2	13.7	56.2	46.2	7.5	58.7	33.7	18.7
Filamentos "	1.25	3.7	1.2		5.0	2.5	21.2		6.2
Flagellate "	46.2	12.5	6.2	56.2	32.5	7.5	30.0	33.7	11.2
Colonial "									
Pediastrum									
Scenedesmus									
Ehtreptia					8.7				
Total diatoms	6.2	28.7	6.2	1.2	10	17.5	37.5		15.0
Total centrales		15.0				5.0			
Total pennales	6.2	13.7	6.2	1.2	10	12.5	37.5		15.0
Cyclotella									
Melosira		15.0				5.0			
Tabellaria floculosa							6.2		
T. floculosa (long)		2.5	1.2		1.2	3.7			2.5
Diatoma									
Meridion	1.2								
Fragilaria									
Asterionella formosa			1.2						
Synedra									
Eunotia	2.5				2.5	1.2	1.25		2.5
Frustulia			2.5						
Navicula		3.7					15.0		5.0
Pinnularia									
P. major									
Gomphonema				1.2	1.2	1.2			
Nitzchia									
Total desmids				3.7					
Cosmarium									
Closterium									
Total chrysophyceae									
Dinobryon									
Total bluegreens		11.2	2.5				13.7	2.5	11.2
Nematodes		3.7	32.5	80.0	425.0		25.0	76.2	83.7
Rotifers									1.2
Ciliates									
Crustaceans								2.5	
X			27.5	15.0		13.7			

Appendix 13. Major taxa of microalgae and invertebrates from Pond D (organism x 10^6 m^{-3}).

Taxa \ Date	05.09.79	17.09.79	10.10.79	30.10.79	13.11.79	27.11.79	18.12.79	08.01.80	21.01.80	25.03.80
Total chlorophyceae	53.3	84.9	39.9	96.6	58.7	112.5	117.5	266.7	67.0	31.2
Filamentos "	0.8	2.4	1.4	4.1	11.2	15.0	2.5	19.2	5.6	
Flagellate "	51.3	77.4	32.4	85.8	46.2	88.7	108.7	220.0	35.2	27.5
Colonial "	0.2									
Pediastrum										
Scenedesmus	0.5	2.4								
Ehtreptia										
Total diatoms	1.7	24.9	5.9	13.3	15.0	3.7		140.2	7.9	20.0
Total centrales		3.3								
Total pennales	1.7	21.6	5.9	13.3	15.0	3.7		140.2	7.9	20.0
Cyclotella										
Melosira										
Tabellaria floculosa										
T. floculosa (long)								13.7		
Diatoma										
Meridion										
Fragilaria										
Asterionella formosa										
Synedra								16.5		
Eunotia										
Frustulia										
Navicula								24.7		
Pinnularia								19.2		6.2
P. major								16.5		
Gomphonema										
Nitzchia										
Total desmids	5.6	11.6	3.4	3.3		3.7	47.5	129.5	240.9	1.2
Cosmarium								121.0	240.9	
Closterium										
Total chrysophyceae						10.0	2.5			
Dinobryon						10.0	2.5			
Total bluegreens	11.5	12.1	24.9	32.4	8.7	25.0		49.5	24.9	3.7
Nematodes	3	5.8	2.4	2.4	10.0				3.4	
Rotifers		1.6								
Ciliates	2.5		0.4							
Crustaceans	0.4	0.8								
X	1.5	1.6	3.4		1.2			110.6	5.6	

Appendix 13 (cont'd).

Taxa \ Date	09.04.80	22.04.80	12.05.80	20.05.80	17.06.80	25.06.80	09.07.80	23.07.80	06.08.80	16.08.80
Total chlorophyceae	92.5	45.0	78.7	37.5	32.5	171.2	2.5	41.2	26.2	1.2
Filamentos "	3.7	6.2				6.2	2.5	32.5	2.5	
Flagellate "	60.0	38.7	72.5	18.7	16.2	161.2		8.7	22.5	
Colonial "										1.2
Pediastrum										
Scenedesmus										
Ehtreptia										
Total diatoms	6.2	6.2	10.0	1.2	3.7		3.7		27.5	1.2
Total centrales										
Total pennales	6.2	6.2	10.0	1.2	3.7		3.7		27.5	1.2
Cyclotella										
Melosira										
Tabellaria floculosa			1.2							
T. floculosa (long)									3.7	
Diatoma										
Meridion										
Fragilaria										
Asterionella formosa		2.5								1.2
Synedra										
Eunotia		1.2	1.2				1.2		2.5	
Frustulia									2.5	
Navicula			1.2						3.7	
Pinnularia							1.2		5.0	
P. major										
Gomphonema					1.2					
Nitzchia										
Total desmids	27.5		3.7				16.2		7.5	3.7
Cosmarium										
Closterium										
Total chrysophyceae			5.0	2.5	10.0	18.5	5.0		1.2	
Dinobryon			5.0		10.0	18.5	5.0		1.2	
Total bluegreens	5.0	6.2			11.2		18.7			8.7
Nematodes					5.0	17.5				
Rotifers					1.2					
Ciliates					1.2					
Crustaceans						2.5			3.7	
X						21.2				

Appendix 14. Changes in bacterial numbers (x 10^{15}) from April 1980-September 1980 in the study ponds.

Date	Pond A			Pond B		
	Bacilli	Cocci	Total	Bacilli	Cocci	Total
09.05.80	6.835 ± 0.65	3.990 ± 0.32	10.826 ± 0.97	5.188 ± 1.66	3.282 ± 0.22	8.471 ± 1.43
22.05.80	1.468	0.675	2.144	1.140 ± 0.08	0.541 ± 0.057	1.682 ± 0.03
12.06.80	8.00 ± 0.15	2.032 ± 0.49	10.038 ± 0.64	9.044 ± 0.18	2.314 ± 0.14	11.358 ± 0.03
20.06.80	9.101 ± 1.84	2.162 ± 0.22	11.264 ± 1.62	11.215 ± 0.87	3.224 ± 0.31	14.439 ± 0.56
09.07.80	0.976 ± 0.01	0.514 ± 0.07	1.491 ± 0.05	1.097 ± 0.159	0.552 ± 0.16	1.649 ± 0.32
23.07.80	11.492 ± 2.93	5.322 ± 1.41	16.815 ± 4.35	16.209 ± 0.21	5.607 ± 1.00	21.816 ± 0.78
06.08.80	1.197 ± 0.004	0.497 ± 0.03	1.695 ± 0.03	1.150 ± 0.10	0.525 ± 0.09	1.666 ± 0.19

	Pond C			Pond D		
	Bacilli	Cocci	Total	Bacilli	Cocci	Total
09.05.80	9.390 ± 2.7	4.50 ± 1.32	13.89 ± 4.08	5.943 ± 2.00	5.494 ± 0.54	11.437 ± 1.46
22.05.80	1.435 ± 0.24	0.502 ± 0.04	2.155 ± 0.01	1.273 ± 0.19	0.559 ± 0.03	1.832 ± 0.22
12.06.80	6.087 ± 0.22	1.624 ± 0.07	7.719 ± 0.29	7.708 ± 1.20	2.700 ± 0.13	10.408 ± 1.06
20.06.80	11.742 ± 0.66	2.267 ± 0.006	13.996 ± 0.67	10.312 ± 0.98	2.803 ± 0.56	13.116 ± 1.55
09.07.80	0.714 ± 0.26	0.575 ± 0.12	1.862 ± 0.43	0.955	0.412	1.406
23.07.80	11.157 ± 2.55	4.382 ± 0.655	15.540 ± 3.21	10.480 ± 1.54	3.991 ± 0.640	16.789 ± 4.50
06.08.80	1.042 ± 0.17	0.437 ± 0.08	1.49 ± 0.27	1.375 ± 0.27	0.625 ± 0.18	2.000 ± 0.45

Appendix 15. Changes in ATP from October 1979-May 1980.

Date	ATP (mg m^{-3}) ± S.E.			
	Pond A	Pond B	Pond C	Pond D
16.08.79	0.704	0.27	0.44	0.26
05.09.79	0.144 ± 0.003	0.054 ± 0.0005	0.106 ± 0.001	0.182 ± 0.003
17.09.79	0.14 ± 0.02	0.15 ± 0.01	0.45 ± 0.10	0.18 ± 0.04
26.09.79	1.24 ± 0.21	0.92 ± 0.30	1.47 ± 0.45	0.75 ± 0.31
10.10.79	0.046 ± 0.036	0.051 ± 0.011	0.036 ± 0.0007	0.037 ± 0.01
30.10.79	0.051 ± 0.011	0.027 ± 0.003	0.020 ± 0.0005	0.080 ± 0.037
13.11.79	0.032 ± 0.002	0.023 ± 0.006	0.016 ± 0.001	0.015 ± 0.003
27.11.79	0.065 ± 0.027	0.015 ± 0.0001	0.023 ± 0.007	0.079 ± 0.011
18.12.79	0.036 ± 0.005	0.029 ± 0.006	0.017 ± 0.004	0.299 ± 0.002
08.01.80	0.193 ± 0.009		0.163 ± 0.016	
21.01.80	0.056 ± 0.017	0.00	0.048 ± 0.032	0.119 ± 0.003
19.02.80	0.110 ± 0.04			
18.03.80	0.186 ± 0.03			0.110 ± 0.025
09.04.80	0.130 ± 0.02	0.069 ± 0.022	0.100 ± 0.02	0.208 ± 0.07
21.04.80	0.152 ± 0.02	0.049 ± 0.009	0.09 ± 0.005	0.080 ± 0.006
13.05.80	0.142 ± 0.009	0.083 ± 0.045	0.068 ± 0.015	0.096 ± 0.03

Appendix 16. Algal production measured by the ^{14}C uptake method - uptake C (mg Ch^{-1} m^{-3}).

Date	Pond A	Pond B	Pond C	Pond D
21.04.80	4.06	0.93	6.06	23.29
12.05.80	7.04	3.97	3.61	36.14
20.05.80	5.75	12.25	9.30	62.88
27.05.80	1.99	25.87		
28.05.80	15.81	10.57		
29.05.80	12.99			41.34
13.06.80	10.70	10.76	30.61	18.08
25.06.80	136.67	83.67	15.66	21.25
24.07.80	1.13	1.44	5.74	42.60