Appendix 19

Maltby Lake
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THE BIOLOGY OF
MALTBY LAKE

BY
RICHARD A. HARVEY
79-4464
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University of Victoria
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Dr. E. Hagmeier

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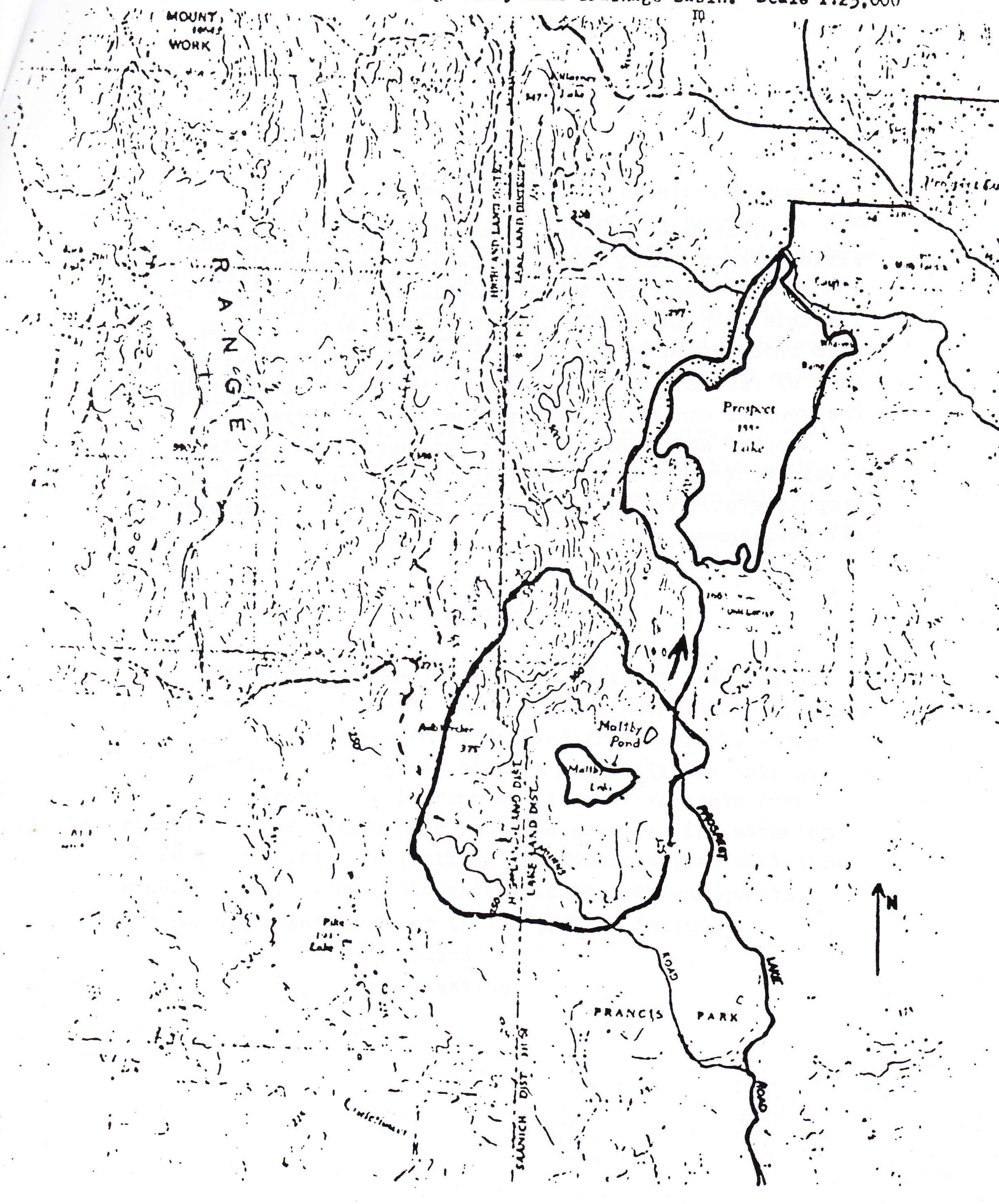


INTRODUCTION

This report is the summation of three months of field work on Maltby Lake from January to March 1981. The report summarizes the data collected and attempts to fit this into an overall picture of the lake's biology. This information is then used to assess the possible impact of residential development in the Maltby Lake basin. The general conclusion is that the lake is currently mesotrophic and leaning towards dystrophy, residential development would shift the lake towards eutrophy if the trophic status of the lake is not considered in the overall development scheme.

HISTORY

The land around Maltby Lake was originally purchased in 1850 by two gentlemen, Mr. Maltby and Mr. Benson. In 1860 the land was sold to Mr. Holmes who initiated a limited farming operation; there are remnants of an orchard on the land today. The property was sold to Mr. Dumbleton in 1886, and was logged in 1935. The property is again owned by Holmes and has not been further developed, although it was selectively logged from 1972 to 1973.

With the recent escalation of land prices in the Victoria area it is likely that Mr. Holmes and his partner, Mr. Pemberton, will soon develop the property or sell it for development.

GEOLOGY

The drainage basin consists of 166.3 hectares of mainly forested highland. The surficial material is composed mainly of particles of rock, derived from bedrock, mixed with dust and some organic matter; generally the soil is poorly developed. The bedrock consists of volcanic rock with layers of metamorphic rock and granite. The metamorphic rocks consist of silicified and feldspathized varieties; amphibolites, garnet, diopside-epidote rock and quartz. The main elements present in the bedrock include:

- Silica
- Potassium

- Magnesium
- Iron
- Sodium
- and Calcium

Silica is the major component of the bedrock, while Calcium is quite rare due to the lack of sedimentary rock. Notably absent from the bedrock is the mineral Phosphate; because of this phosphate is the key limiting factor of the Matlby_Lake system.

GEOGRAPHY

Maltby Lake is a small highland lake located north-west of Victoria ($48^{o}29.8$'N, $123^{o}27$'W). It is a glacial scour lake with a well developed heath at it's major outflow to the northeast, see figure 2. The climate is classed as mediterranean with a cool summer phase, the important feature is the lengthy winter rains. The major geograghic parameters are summarized in table 1.

table 1. Maltby Lake, geograghic parameters.

drainage basin area- 159.7 hectares (excluding lake)
166.3 hectares (including lake)

land use:

1)Forest	55%	
2)Agriculture	1-5%	
3)Commercial	1%	(auto wrecker)
4)Utilities	20%	(B.C. Hydro line)
5)Park	15%	
6)Residential	1-5%	(approximately 30 people.)

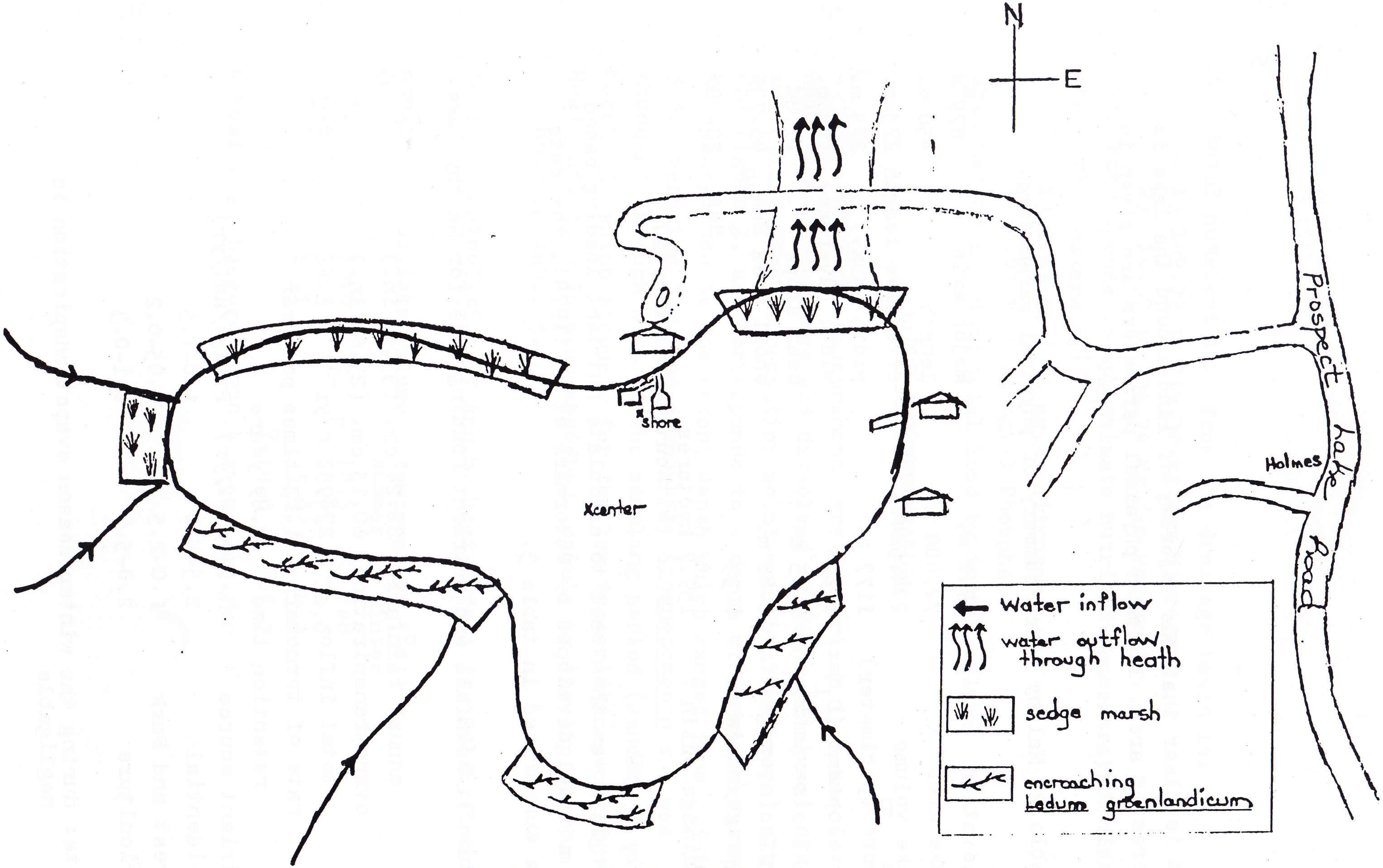


figure 2. Map of Maltby Lake

It is clear that the majority of land around the lake is forested area. The main physical parameters are given in table 2.

table 2. Maltby Lake, summary of physical parameters.

elevation	79.2 m.	major axis	N79°W
lake area	72,400 m^2	length	450 m.
lake volume	204,524.5 m^3	effective length	275 m.
shore (perimeter)	1177 m.	width (max.)	275 m.
development (D_1)	1.234	width (average)	173 m.
depth (maximum)	8.15 m.	mean slope	11.8%
depth (average)	2.82 m.	shoal area ShA_{20}	46.73%
average/maximum	0.35	ShA_s	22.00%
drainage basin	159.7 hectares (without the lake area)		

The data was then used to calculate nutrient loading based on a model developed by Uttormark et al (1974), the data are summarized in table 3.

table 3. Rainfall and Nutrient Loading data for Maltby Lake.

annual rainfall	88.24 cm. (33.56 in.)	
evapotranspiration	60.15 cm. (23.68 in.)	
total inflow*	230932 $m^3 yr^{-1}$	
rate of turnover	1.13 times per year	
retention time	0.89 years	
nutrient source	N (kg/ha./yr)	P (kg./ha./yr)
Residential	2.5-5.0	1.0-1.5
Forest and Park	1.0-2.5	0.05-0.2
Agriculture	2.0-5.0	0.1-0.3

*note: during the winter season evapotranspiration is negligable

The total nutrient load from the drainage basin is:

1) 149.73 to 359.32 kg./yr Nitrogen
2) 14.37 to 36.74 kg./yr Phosphate.

This corresponds to approximate nutrient concentrations in the inflow waters of:

1) 0.65 to 1.56 mg./l Nitrogen
2) 0.07 to 0.18 mg./l Phosphate

obtained by dividing total load by total inflow.

LIGHT AND TEMPERATURE

The light measurements are summarized in table 4, while the temperature and dissolved oxygen readings are shown in table 6. The compensation point was obtained graphically, see figure 3, and corresponds to a depth of 3.5 meters. This is quite close to the secchi depth which ranged from 2.5 to 3.5, averaging 3.2. The cyanophyte Aphanezomenon sp. was abundant through most of the sampling period (January 9 to March 25) which accounts for the low transmittence of light. Heat radiation is also absorbed, mainly by the top stratum as shown in table 5.

table 5. Calculation of Annual Heat Budget for Maltby Lake.

stratum (m.)	% of lake volume	temperature (°C.) summer	winter
0-3.3	50.6	18.3	7.8
6.6	39.3	10.7	4.6
8.2	10.1	5.0	4.2
		$\overline{X}$=14.0	$\overline{X}$=6.2

Annual Heat Budget= 2,220.4 g-cal./cm./yr table 4. Light readings taken at Maltby Lake March 25, 1981 using Ambient (Deck) Cell

- cloudy skies
- cell condition #4, no accessory filters

	DEPTH	UNRADIATED RANGE	READING	INTENSITY mW/cm²	INTENSITY g-cal/cm² min	transmittance %	[illegible]
	0	10K	2.9	49	0.4007	100	[illegible]
	1	1K	4.5	7.88	0.1127	16.08	[illegible]
	2	300	5.0	2.63	0.0376	5.37	[illegible]
3:30pm	3	100	5.3	.93	0.0133	1.90	[illegible]
	4	10	9.4	.16	0.0023	.33	[illegible]
	5	10	1.5	.03	0.0004	.06	
	6	10	0.3	.00	0	0	
	7	10	0	.00	0	0	
	0	10K	0.6	10.5	0.1502	100	[illegible]
	1	100	8.1	1.47	0.0210	13.98	[illegible]
	2	100	3.4	.60	0.0086	5.73	[illegible]
4:30pm	3	30	4.6	.24	0.0034	2.26	[illegible]
	4	10	3.5	.06	0.0009	.60	[illegible]
	5	10	0.9	.02	0.0003	.20	
	0	300	6.9	3.62	0.0518	100	[illegible]
	1	100	4.7	.82	0.0117	22.59	[illegible]
	2	30	5.9	.31	0.0044	8.49	[illegible]
5:30pm	3	10	6.5	.11	0.0016	3.09	[illegible]
	4	10	2.2	.04	0.0006	1.16	[illegible]
	5	10	0.5	.01	0.0001	.19	

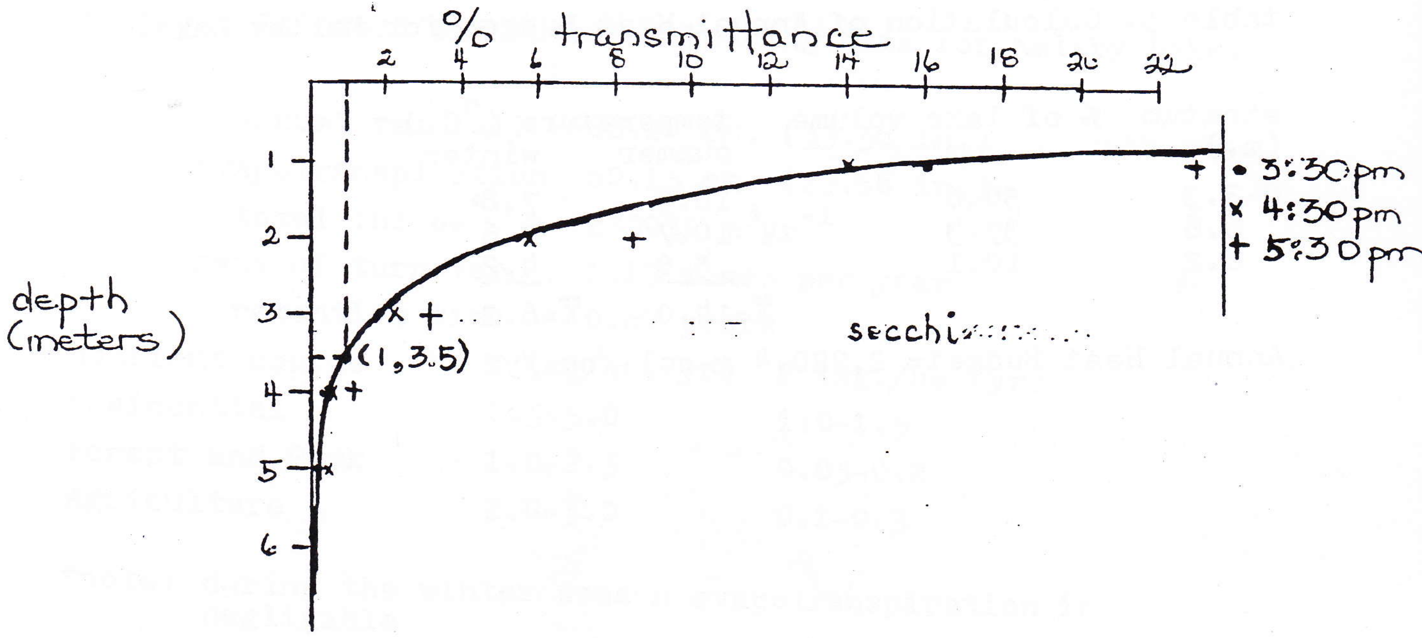


Figure 3. Graph of % transmittance

table 6. Summary of temperature, pH, conductivity and dissolved oxygen (O_2) data from Maltby Lake, 1980-1981.

Depth (m.)	12/6	07/7	09/1	21/1	24/1	31/1	07/2	14/2	21/2	28/2	08/3	11/3	14/3	21/3	25/3
air	16.5	-	8.1	8.5	4.7	4.5	4.7	10.6	9.7	15.7	14.2	13.6	12.3	13.1	15.9
0	19.2	19.4	5.0	4.3	5.2	4.1	3.7	5.0	4.9	7.0	9.9	9.7	9.2	10.6	12.2
1	17.8	18.9	4.8	4.3	-	-	3.7	4.9	4.7	-	-	8.2	8.5	10.0	11.5
2	14.8	18.3	4.6	4.3	-	3.8	3.7	4.8	4.7	-	7.7	7.4	7.6	9.3	9.9
3	10.8	16.7	4.6	4.2	4.0	-	3.7	4.7	4.5	-	-	6.5	5.7	7.5	7.5
4	6.9	12.5	4.5	4.0	-	3.7	3.6	4.7	3.9	-	4.5	4.4	4.2	5.9	6.1
5	4.1	8.3	4.2	3.9	-	-	3.6	4.7	3.4	-	-	4.0	3.8	5.0	5.2
6	3.2	5.6	4.0	3.7	-	3.7	3.6	4.7	3.7	-	4.1	4.0	3.8	4.7	5.0
7	2.8	4.4	4.2	3.7	-	-	3.6	4.7	3.6	-	-	4.0	3.9	4.8	5.0
8	-	-	4.2	3.6	3.7	3.8	3.6	4.5	4.0	-	4.1	4.2	4.0	4.9	5.1
9		-	4.4	4.0		-	-	5.1	4.3	4.5	-	-	-	-	-
pH					6.6		6.4								
cond (umhos/cm.)					59		68						55	55	
secchi (m.)	5.0	4.8	3.3	3.5	3.3	3.2	3.3	2.5	2.5	-	3.0	3.6	3.6	-	3.2

*temperature readings in °C.

Depth (m.)	12/6	07/7	09/1	21/1	24/1	31/1	07/2	14/2	21/2	28/2	08/3	11/3	14/3	21/3	25/3
0				8.2	7.7	9.0	9.5	7.4	8.2	11.5	10.6		15.0	15.2	
2				8.0	7.4	9.0	9.4	8.3	8.0	11.0	8.3		12.2	14.5	
4				7.8	7.4	9.0	9.4	8.7	7.8	10.1			10.1	14.7	
6					6.8	9.0	9.4	5.5		9.9	6.0		9.4	10.6	
8				6.6	6.3	7.0	9.3	6.0	6.6				6.0	8.3	

**oxygen readings in mg./l.

The oxygen data reveals that, contrary to what one might expect, the amount of oxygen in the water actually increases as the temperature of the water increases during the spring months. It appears that an increase in the photosynthetic activity of submergent and floating-leaved aquatic macrophytes is oxygenating the water.

LAKE SEDIMENT

There are two types of sediment found at Maltby Lake; the littoral and sublittoral zones have a light brown dy sediment, while the benthic zone has a much darker gyttja sediment. Both sediments contain humic and non-decomposed organic fragments(mainly plant), algal remains, diatom frustules, pollen grains and invertebrate exoskeletons. The main difference is that the dy sediment is higher in inorganic nutrients, resulting from decomposition, while the gyttja has a higher organic content, thus the darker colour. The sediments were split into various particle size components, see table 7; the sediment consists of silt, non-decomposed organic matter and sand.

table 7. Sediment fractions obtained by washings through various sieves (Munteanu,N.)

sieve #	CENTER wt. of fraction (g.)	CENTER % of total	SHORE wt.(g.)	SHORE % of total
10	0.01	0.3	0.08	3.7
20	0.01	0.3	0.03	1.4
40	0.06	2.0	0.16	7.4
sand 60	0.31	10.5	0.23	10.6
120	0.48	16.2	0.52	24.1
200	0.37	12.5	0.23	10.6
silt 200+	1.72	58.1	0.91	42.1

Chemical tests were also done on the sediment samples, they are summarized in table 8. Although the shore sediments are of greater organic content, due to fall leaf drop, the phosphate and potassium component is less than that of the lake center sediment. This is likely due to ion uptake by the macrophytes of the shore, as well as leaching of ions or minerals from the shore to the benthos. Figure 4 shows the apparent building up of the littoral and sublittoral areas.

table 8. Chemical test results for lake sediment.

test	lake center	lake shore	
Organic Carbon	53.7%	63.2%	-by weight
Phosphate	22.4	16.8	- g./m^2
Potassium	20.2	12.9	- g./m^2
hydrometric test	2%	2.5%	
pH	5.9	6.2	
colour	dark brown	light brown	
soil type	gyttja	dy	

SEDIMENT DIATOMS

A sediment core was taken from the lake center, and samples from 17 strata were analyzed. Figure 5 shows the relative abundance of the various diatom genera encountered, and the approximate age of each stratum. Table 8a lists the values for the two diatom indices calculated for each statum, and gives the approximate depth of the stata.

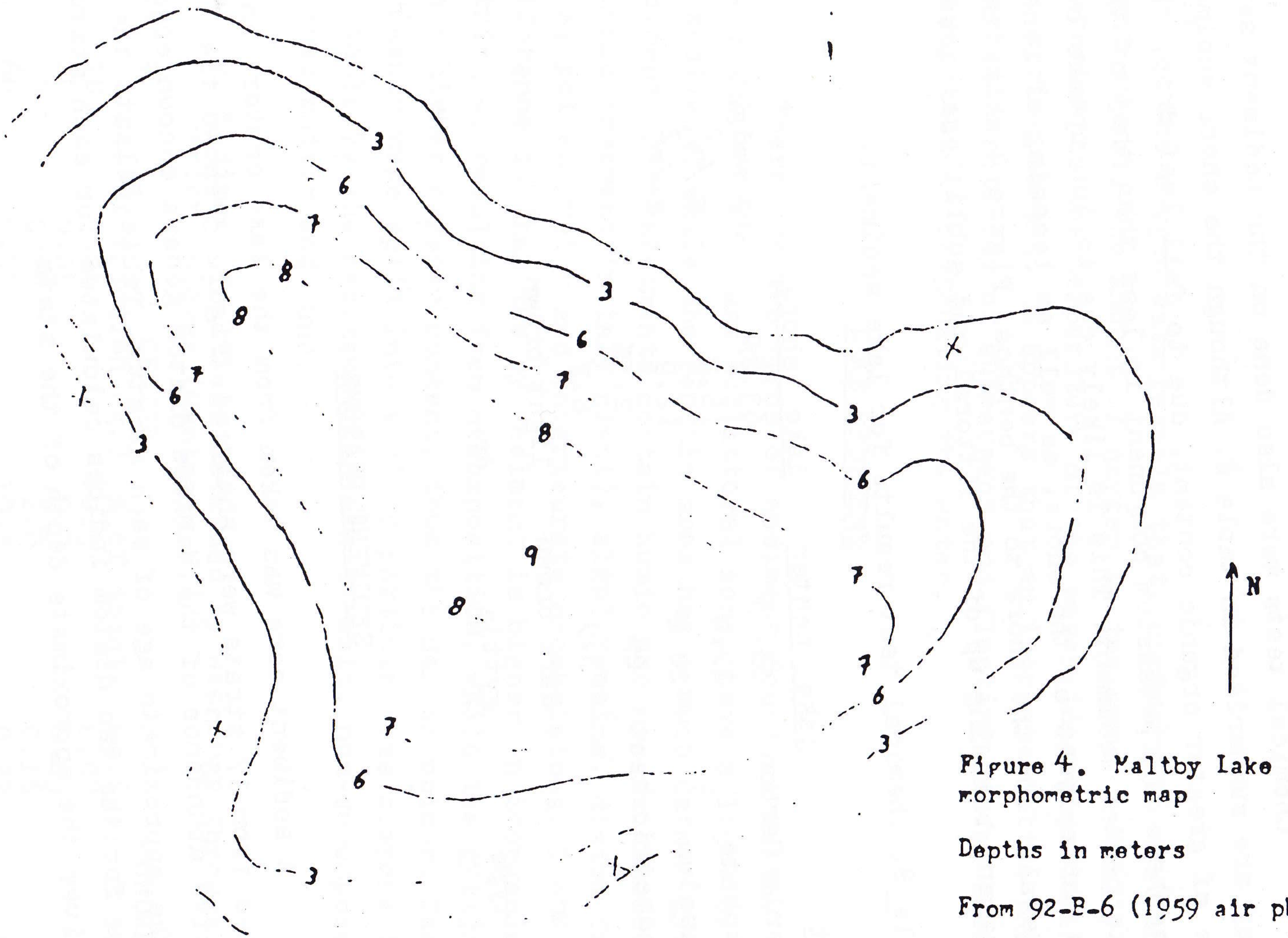


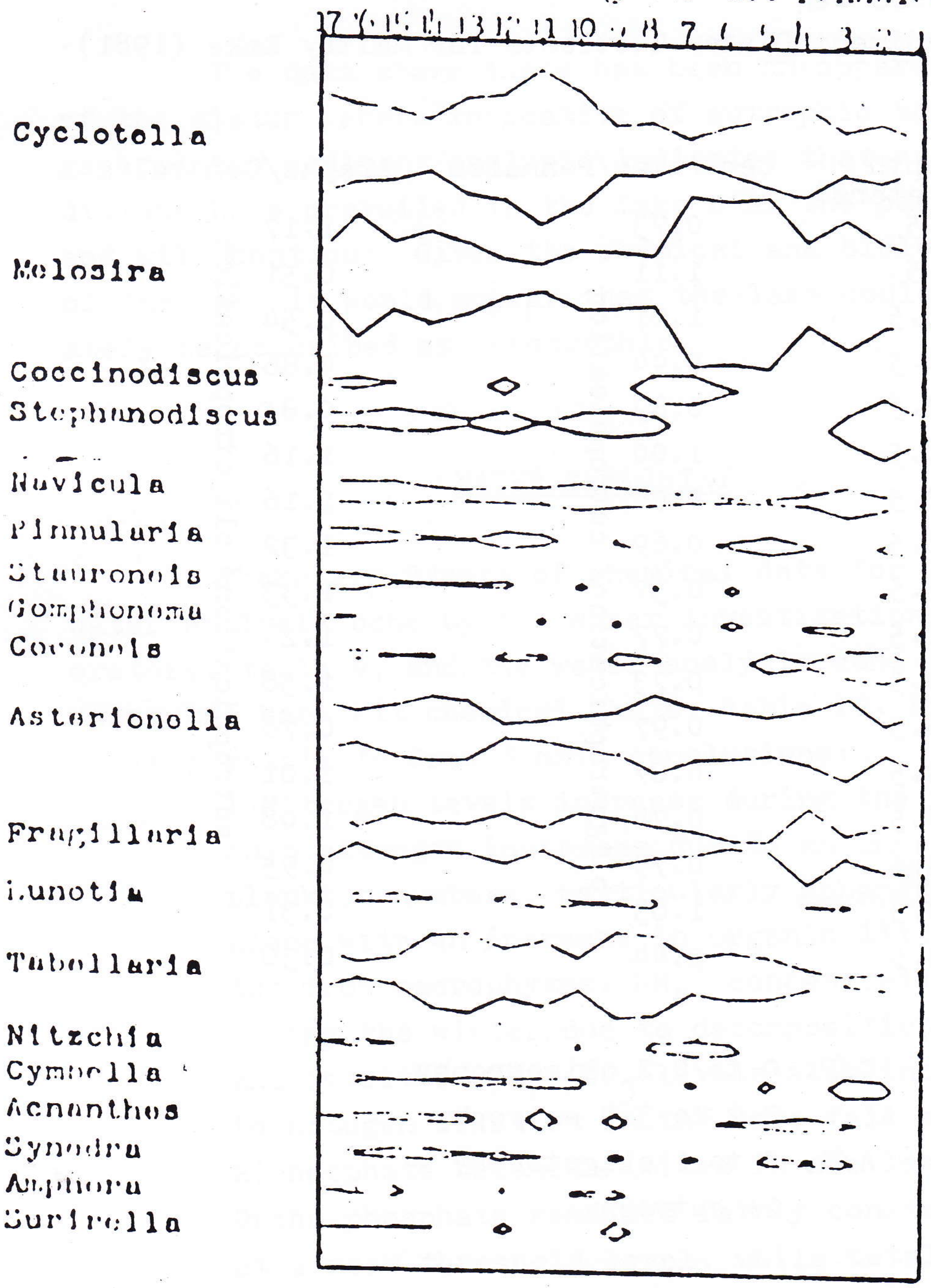
Figure 4. Maltby Lake morphometric map

Depths in meters

From 92-B-6 (1959 air photo)

Scale 1:2280

Figure 5: Percentage Abundance Histograms, of sediment diatoms found in a sediment core of 85 cm. Genera are tabulated with Centrales comprising the upper four histograms and Pennales the rest.



The sediment core was sampled in 5 cm segments. The sample numbers are listed here with their corresponding year of deposition. See text for sedimentation rate.

Sample		Year
1	-	[illegible]
2	-	[illegible]
3	-	[illegible]
4	-	[illegible]
5	-	[illegible]
6	-	[illegible]
7	-	[illegible]
8	-	[illegible]
9	-	1780
10	-	1755
11	-	1730
12	-	1705
13	-	[illegible]
14	-	1655
15	-	1630
16	-	1605
17	-	[illegible]

TABLE 8a.

Sediment Diatom Quotients for Maltby Lake (1981)

depth (meters)	Centrales/Pennales	Araphs/Centrales
0-3.5	0.73	1.17
8.5	1.11	0.51
13.5	1.01	0.54
18.5	0.94	0.86
23.5	0.89	0.85
28.5	1.00	1.16
33.5	0.96	1.16
38.5	0.69	1.32
43.5	0.57	1.33
48.5	0.77	1.24
53.5	0.73	1.58
58.5	0.97	0.78
63.5	0.87	1.01
68.5	0.78	1.08
73.5	0.79	0.95
78.5	1.63	0.31
83.5	2.44	0.30

(Centrales/Pennales: oligotrophication/ eutrophication)

(Araphs/Centrales: eutrophication/ oligotrophication)

C/P, 0 to 0.2 oligotrophy
0.2 to 3.0 eutrophy

A/C, 0 to 1 oligotrophy
2+ eutrophy

The data shows there has been an apparent cycling of the diatom genera indicative of eutrophic conditions. In general the sediment analysis indicates that eutrophic conditions have prevailed in the lake over the past 400 years, and will continue. Given the chemical and biological status of the lake it would appear that the lake could more accurately be described as mesotrophic.

WATER CHEMISTRY

There are 2 sets of chemical data for Maltby Lake; water analysis done by the Water Investigations Branch laboratory, table 9, and the water analysis done by the group using the Hach kit chemical tests, table 10. From the data it is possible to draw 5 main conclusions:

1)Nitrogen levels increase during the winter. Organic nitrogen increases due to an increases in plankton numbers, particularly Aphanezomenon sp., along with an increase in organic litter and detritus from macrophytes. NH_4^+ concentration rises during the winter due to decomposition of litter and detritus. NO_2, NO_3 levels also increase due to nitogen fixation in the late fall and winter.

2)Phosphate becomes limited in the lake system. Ortho-phosphate remained fairly constant, probably at a near threshold level, while total phosphate increased during the winter due to decomposition of litter and increased phytoplankton.

3)Specific conductance indicates an abundance of anions (eg. Cl^-, NO_3^-, PO_4^-, SO_4^-, CO_3^{2-}), alkalinity readings show a moderate concentration of

Table 9. Water Chemistry, from [illegible] Laboratory for [illegible]

Chemical [illegible] (cont'd)	June 12, 1980 0m	2.5m	5m	January 21, 1981 0m	4m	8m
pH	7.4	7.4	7.2	6.4	6.9	6.9
spec cond (umho/cm)	102	[illegible]	95	94	94	94
alkalinity, total (mg/L)	21	21.[illegible]	[illegible]	21	20.9	20.6
chlorine (mg/L)	8.7	8.0	7.[illegible]	-	-	-
nitrogen: (mg/L)						
-organic	.03?	.56	.32	.39	.34	.37
-NH4+/[illegible]	[illegible]	.047	.05	.099?	.093	.06
-NO2 > NO3	.02?	.0[illegible]	.02	.04?	.0[illegible]	.07?
-kjeldahl	.3[illegible]	[illegible]	.37	.4[illegible]	.77?	.48
-total	.3[illegible]	[illegible]	.39	.52	[illegible]	.52
[illegible] (mg/L)						
-ortho	[illegible]	.003?	.003	.003?	.003	.03?
-total	.001?	.01	.009	.014	.015	.014
carbon: (mg/L)						
-organic	[illegible]	[illegible]	5	7	7	6
-inorganic	3	5?	7	4?	7	7
[illegible] (mg/L)						
-dissolved	8.2	9.[illegible]	[illegible]	9.6	9.6	9.6
-total	10	9.3?	[illegible]	9.8?	9.8	9.8
CO2 (mg/L)	[illegible]	3[illegible]	34.4	33.0	33.0	33.4
[illegible] (mg/L)						
-dissolved	2.2	[illegible]	2.3	2.2	2.2	2.3
-total	[illegible]	[illegible]	2.4?	2.5?	2.3	2.7
[illegible] reactive (mg/L)	7.[illegible]	[illegible]	4.5	6.3	6.2	6.2
turbidity (JTU)	.4?	[illegible]	.7	-	-	-
color:						
-true						
-[illegible]	5	[illegible]	16	30	40	30
residue: (mg/L)				-	-	-
total 105 C	[illegible]	6?	70?	-	-	-
filterable 105 C	[illegible]	[illegible]	[illegible]	-	-	-
[illegible] 105 C				-	-	-

fixed CO_2. There are high concentrations of Ca^{2+}, Mg^{2+}, and $CaCO_3$ which govern the pH buffering capacity of the lake water. These factors did not change appreciably from summer through spring, which demonstrates the overall stability of the lake's chemical environment.

4)C, Ca, $CaCO_3$, alkalinity, specific conductance and pH readings, taken at the 3 depths, indicate a tendency towards isochemical conditions during the winter; i.e. the lake is turning over albeit slowly.

5)The decrease in pH and increase in Silica during the winter is a result of increased precipitation which causes a slight dilution of lake water and an increase in minerals from the drainage basin.

table 10. Hach kit chemical data from Maltby Lake.

test	February 28			March 25,1981		
depth= (meters)	0	4	8	0	4	8
pH	7.05	6.85	6.75	7.3	6.9	6.6
conductivity	75	90	130	80	90	135
P total	1.30	0.45	0.25	0.03	0.02	0.02
P ortho	0.07	0.10	0.28	0.08	0.08	0.20
NH_3	0.40	0.50	0.60	0.25	0.45	0.35
NO_3	0.5	0.3	0.5	0.5	0.5	0.3
NO_2	.009	.010	.012	.008	.010	.006
hardness(Ca)	30	40	50	30	45	45
alkalinity	20	25	20	20	25	20
Silica	2.7	3.0	2.8	5.2	2.4	2.2
$CaCO_3$	45	60	85	25	25	25

concentrations in mg./l.

table 11. Oxygen saturation calculations for Maltby Lake 1981.

date	depth= 0	2	4	6	8 (meters)
January 21	63.5	61.5	59.5		49.4
24	60.5				47.4
31	69.5	67.5			
February 7	72.6	71.5	70.5	70.5	69.5
14	58.4	64.5	68.5	42.3	46.3
21	63.5	61.5	59.5		51.4
28	93.7				
March 8	92.7	68.5	47.4		46.4
11	52.4				
14	130.0	100.8	76.6	71.6	45.4
21	135.0	126.0	115.9	82.6	64.5
25				39.3	20.2

* readings in % saturation

The dissolved oxygen data, shown in table 11 above, indicates a gradual oxygenation of the lake water as summer approaces. This could be due to an increase in photosynthetic activity of the macrophytes as well as a decrease in O_2 demand by the nitrogen fixing plankton <u>Aphanezomenon</u> sp., which appear* to decrease in abundance after the winter. It should be noted that the measurements are consistently inflated because the dissolved oxygen measurements were made using mini-Winkler tests (Munteanu,N.); thus the values greater than 100% saturation.

* see discussion of Phytoplankton

PLANKTON

The results of the plankton survey are summarized in tables 12 and 13. The general trend appears to be a seasonal shift in phytoplankton from a diverse summer/early fall community to a winter phase composed primarily of the cyanophyte Aphanezomenon sp. The ability of some cyanopytes and in particular Aphanezomenon sp. to thrive under low nitrogen and phosphate conditions has been investigated by Lindahl, G. et al. He concludes that nitogen-fixing plankton can occur in low nutrient environments, although the rate of nitrogen fixation is dependent upon nutrients. At Maltby Lake the diverse summer plankton community gradually becomes dominated by diatoms, cyanophytes and pyrrhophyte in the late fall, which give way to the predominantly cyanophyte community of winter. It seems that Aphanezomenon sp. is able to survive the low nutrient conditions which preceed fall turnover in the lake. Once fall turnover has begun, there is a slow but steady release of nutrients, particularly phosphate, from the sediments which enhances the nitogen fixation process. It was noted in the water chemistry analysis that silica is quite plentiful, this would account for the abundance of diatoms.

The zooplankton community was studied from January 9 through March 21, 1981. Copepods were common although not abundant. The fact that zooplankton cannot feed on Aphanezomenon sp., probably due to a form of chemical protection, coupled with the the cold winter temperatures would account for the seemingly sparse zooplankton community.

TABLE 12.

Summary of Phytoplankton data from horizontal surface tows at Maltby Lake center.

	31/11/72	12/6/80	1981 09/1	21/1	14/2	21/2	14/3	21/
EUGLENOPHYTA								
Euglenales								
Euglena sp.		f						
CHLOROPHYTA	*	*	*	*	*	*	*	*
Volvocales								
Volvox sp.	c		f	r				r
Chlorococcales								
Ankistrodesmus sp.								r
Chlorella sp.		r						
Oocystaceae sp.		r						
Desmidiales								
Desmidium sp.	c							
Staurastrum sp.	c							
CYANOPHYTA	*	*	*	*	*	*	*	*
Chroococcales								
Croococcus sp.		r						
Hormogonales								
Aphanezomenon sp.	d		d		r-f	r	r	r
Oscillatoria sp.	c							
CHRYSOPHYTA	*	*	*	*	*	*	*	*
Chrysophyceae								
Ceratium sp.		c						
Dinobryon sp.	a	r						
BACILLARIOPHYTA	*	*	*	*	*	*	*	*
Pennales								
Asterionella sp.	c							
Fragillaria sp.	c	r						
Stauroneis gracilis		r						
Tabellaria fenestrata	a							
T. *flocculosa*	c	r						
PYRRHOPHYTA		*	*	*	*	*	*	*
Peridiniales								
Peridinium sp.	d	r-f						

r, rare
r-f, rare to fairly common
f, fairly common
c, common
a, abundant
d, dominant

TABLE 13

Phytoplankton and zooplankton from vertical tows taken from Maltby Lake, 1981.

date	09/1		21/1		14/2		21/2		14/3		21/3	
depth (meters)	2	5	2	5	2	5	2	5	2	5	2	5
PHYTOPLANKTON												
Volvox sp.	r					f		r				r
Ankistrodesmus sp.											r	
Closterium sp.					r	f						
Aphanezomenon sp.	a	a	a	a	c	c	a	a	f	c	c	a
Pinnularia sp.						r						
ZOOPLANKTON	*	*	*	*	*	*	*	*	*	*	*	*
Copepoda												
Calanoid	f	r	c	f	c	c		r	c	f	r	r
Cyclopoids		f	r					f				
Nauplius	f	f	r	a	r	r		r	r			
Ciliata												
Epistylis sp.	f					r			f	f	r	r
ciliate								r				
Cladocera												
Daphnia sp.									r	f	r	r
Ceratodaphnia sp.								r			r	r

a, abundant
c, common
f, fairly comm
r, rare

TABLE 14

Estimate of Phytoplankton Primary Production by Light-Dark bottled oxygen method.

depth (Z)	dark bottle O_2	light bottle O_2	difference*
0	10.1 mg./l	10.2 mg./l.	0.1 mg./l.
1	10.1	10.2	0.1
2	9.9	9.8	-0.1
3	10.0	10.0	0
4	8.7	8.9	0.2
5	7.4	7.5	0.1

*results indicate effectively no 1^{o} production

note: sample taken during decline in Aphanezomenon sp.

Table 14 shows the calculations of O_2 production using the light-dark bottle method to approximate primary production, see Munteanu,N.. The results indicate no primary production; this is due to the fact that we carried out the test on March 25, just as <u>Aphanezomenon</u> sp. was dieing out. The plankton community competes with the macrophyte community for nutrients (Hill, B.H.), so I would expect plankton production to remain low until later in the spring or early summer. Figure 6 shows the general annual cycle.

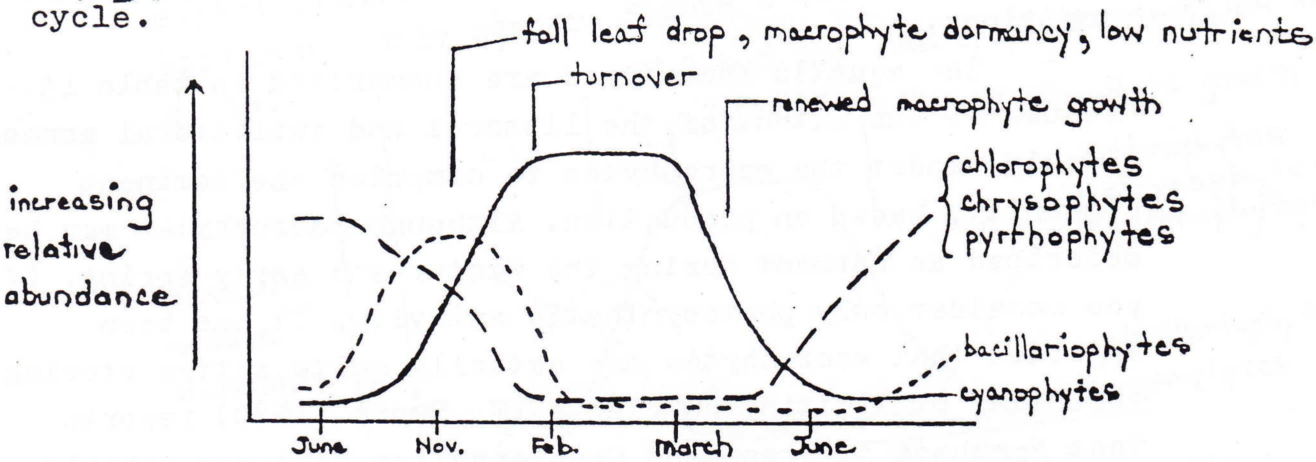


figure 6. Diagram showing annual phytoplankton cycle.

PERIPHYTON

The periphyton component of a lake system is one important link in the release of nutrients (NH_4^+ in particular) from the sediments (Jansson, M.). This study lacks an analysis of periphyton in Maltby Lake, although this certainly does not imply any insignificance of this component.

MACROPHYTES

Maltby Lake is surrounded by highland forest composed mainly of Pseudotsuga menziesii, Tsuga heterophylla, Thuja plicata, and Arbutus menziesii. The south shore of the lake is partially covered by Ledum groenlandicum, a plant which generally indicates low nutrient or dystrophic conditions.

The aquatic macroflora are summarized in table 15. Because of the extent of the littoral and sublittoral zones, I would expect the macrophytes to comprise the dominant community, based on production. Although macrophytes may be described as dormant during the winter and early spring, if you consider only photosynthetic activity, it has been reported that macrophytes are actually quite active storing essential or limiting nutrients. M. Smart (1980) reports that Nymphaea tuberosa and Ceratophyllum demersum exhibit the highest concentrations of phosphate in the late autumn, while nitrogen is highest in the spring. The petiole and the rhizome are the primary storage locations. Nymphaea was dormant during the winter while Ceratophyllum remained actively growing except during the 3 coldest weeks of winter. B. Hill (1979) reports that Potamogeton nodosus accummulates phosphate and nitrogen constantly, mainly through the rhizome. Uptake during the winter is stored for use in the summer months when nutrients are depleted. This allows macrophytes to outcompete and effectively limit phytoplankton growth, while enhancing macrophyte production.

The process of nutrient uptake requires the expend-

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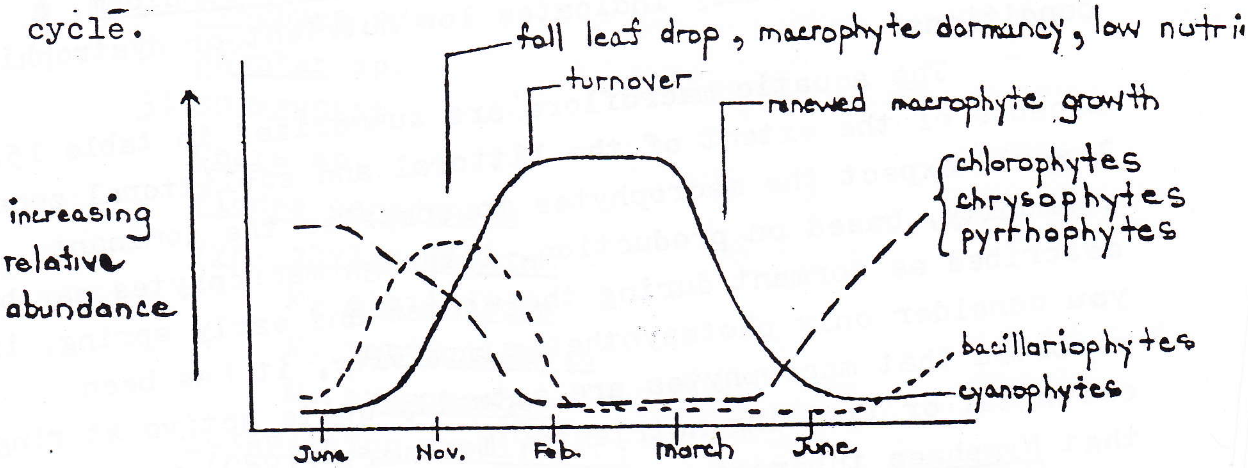

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TABLE 15

Species list of Aquatic Macrophytes at Maltby Lake, January 1981.

1) EMERGENT
   Typha latifolia
   Scirpus lacustrus
   Carex spp.
   Juncus spp.
2) FLOATING LEAVED MACROPYTES
   Nymphaea sp.
   Newphar sp.
3) SUBMERGENT
   Chara sp.
   Elodea canadensis
   Myriophylla ceratum
   M. elatinoidea
   M. verticillatum
   M. exospecense
   Potamageton amplifolius
   P. robinseii
   Fontinatio antipyretica
   Anthifolius sp.
4) FREELY FLOATING
   Lemna sp.
5) SHORE (ENCROACHING)
   Ledum groenlandicum
   Potentilla palustrus

iture of energy, which is obtained through photorespiration and normal respiration of stored carbohydrates. S. Jana(1979) experimented with Potamageton sp. and found that decreasing temperature is corrolated with increasing photorespiration in the winter. To demonstrate the ion (nutrient) uptake ability of aquatic flora A. Mickle and R. Wetzel (1978) analyzed the water chemistry of the inflow and outflow waters of Scirpus subterminalis and Myriophylla heterophyllum stands. They found that Scirpus had no effect on phosphate concentration, while Myriophylla removed 30% of the phosphate from the water. Both plants reduced the alkalinity and Calcium content by 40 to 45%.

Because the macrophyte community is the dominant primary producer in many lake systems, aquatic botanists have studied the uptake of CO_2 by aquatic plants. CO_2 uptake is regulated by the enzyme carbonic anhydrase, which converts CO_2 and H_2O into H^+ and HCO_3^-; the ion is then transported. C. Weaver and R. Wetzel (1980) found that carbonic anhydrase activity was proportional to the amount of primary production. Using this, they determined the contribution of various aquatic plants to production. The results indicate that emergent plant production is greater than floating-leaved plant production which is greater than submergent production.

In general floating-leaved and emergent macrophytes appear to contribute the most biomass to the litter and detritus of the lake. More research is needed to fully assess the extent to which aquatic macrophytes interact with and alter their environment.

INVERTEBRATES

Table 16 lists the invertebrates found at Maltby Lake. The invertebrates are mainly detritivors and herbivors functioning in the recycling of plant material and minerals through the lake system. There were also two predator species, Chaorborus sp. and Libellula lydia.

The concept of bioturbation has been examined in the literature. One study by G. Holdren Jr. and D. Armstrong (1980) quantifies the release of phosphate during the emergence of chironomids. Emergence is linked to increased temperature or decreased oxygen concentrations in the water, and result in the release of 51 mg./m^2/day of phosphate from the sediments. The actual process releasing the phosphate, and the fate of the phosphate released is not understood, The hypothesis is put forth that the chironomid's digestion or pupation causes the release of phosphate which is taken up by macrophytes or reabsorbed by the sediment.

BACTERIA

The water at Maltby Lake was tested for bacterial activity and coliforms using the B.O.D. and coliform tests described by N. Munteanu. The results, summarized in table 17, suggest the absence of microbial activity in the water. The microbial activity may be restricted to the sediments of Maltby Lake, and is likely most evident in the fall after

TABLE 16.
Invertebrates found in sediments of Maltby Lake, March 11/1981.

PROFUNDAL	
Diptera	
Chaoborus sp.	common
Calopsectra sp.	rare
*note: numerous eggs also found (likely Daphnia or Copepod)	
LITTORAL	
Amphipoda	
Ayalella _azteca_	common
Copepoda	
Cyclopida sp.	fairly common
Coleoptera	
larva	rare
Diptera	
Chaoborus sp.	common
Calopsectra sp.	common
Odonata	
Libellula _lydia_	fairly common-rare

leaf drop, of terrestrial and aquatic vegetation. B.Hill (1979) reports that macrophyte decomposition occurs in two phases. The first eight days comprise phase 1 during which time 21 to 60% of the dry weight is lost due to leaching of nutrients and breakdown of small organic molecules. The second phase lasts 42 to 56 days, essentially completing the decomposition of larger structural and cellular compounds. Hill also reports that nitrogen levels are a limiting factor in microbial activity. G. Godshalk and R. Wetzel (1978) found that O_2 availability and temperature effect the rate of decomposition. They also showed that the emergent flora decompose much slower than floating leaved plants due to the greater proportion of cellulose, hemicellulose and lignins; which are very resistant to decomposition. A. Guadiosa and C. Boyd (1978) studied the rate of decomposition of the cyanophyte Anabaena sp. and concluded that it's higher nitrogen content caused a faster rate of decomposition than Typha, a macrophyte.

Coliforms were found at Maltby Lake which suggests that the septic tanks around the lake are leaking sewage into the lake water.

TABLE 17.

Summary of BOD and Coliform Test results for Maltby Lake, March 25, 1981.

BOD

site	[O_2] in ppm. day 1	2	3	4	5	conclusion
control	45	45	45	45	45	no decomposition
Northwest shore	25	25	25	25	25	no decomposition
East (by cabin)	25	25	25	25	25	no decomposition
East (marsh)	0	0	0	0	0	no decomposition*
Southeast shore	35	35	35	35	35	no decomposition

*possible anaerobic decomposition

COLIFORMS

site	presumptive 24 hr	presumptive 48 hr	confirmative 24 hr	confirmative 48 hr
control	-	-	-	-
Northwest shore	-/+	-/+	-/+	-
East (by cabin)	-	-/+	-	-/+
East (marsh)	-	-	-	-
Southeast shore	-	-/+	-/+	-/+

Hach test/Nina's test

CONCLUSION

From the information gathered, it is evident that phosphate and nitrogen concentrations are the two key limiting factors governing Maltby Lake's biology. The fact that the macrophytes are able to store both of these essential nutrients explains the apparent dominance of the macrophyte community. This indicates oligotrophy, although it has been suggested that the buildup of sediment and the abundance of the aquatic weed Myriophylla spp. indicates the lake is bordering upon eutrophy. Periphyton, sediment invertebrates and bacteria all function to recycle the nutrients shed by the macrophytes during leaf drop in the fall. Decomposition provides essential nutrients by the time turnover begins in winter. The lake's sheltered locationand the small size of the lake act to limit the rate of turnover; which is convenient as the flushing of nutrients out of the system is kept minimal. Figure 7 gives a pictorial summary of the nutrient cycle in Maltby Lake.

Table 18 lists rainfall chemistry data for three dintinct locations. I could not find data for precipitation in the Victoria area, however I would expect overall ion concentrations to be lower due to the lower ambient temperatures. The importance of nutrient input by rainfall has not been well documented. It would appear that as eutrophication of the biosphere in general continues (Hutchinson, G. 1970) that rainfall will become an increasingly important factor governing biological systems. A. Lynch (1969) reports phosphate in dust which would result in 279.08 grams of phosphate

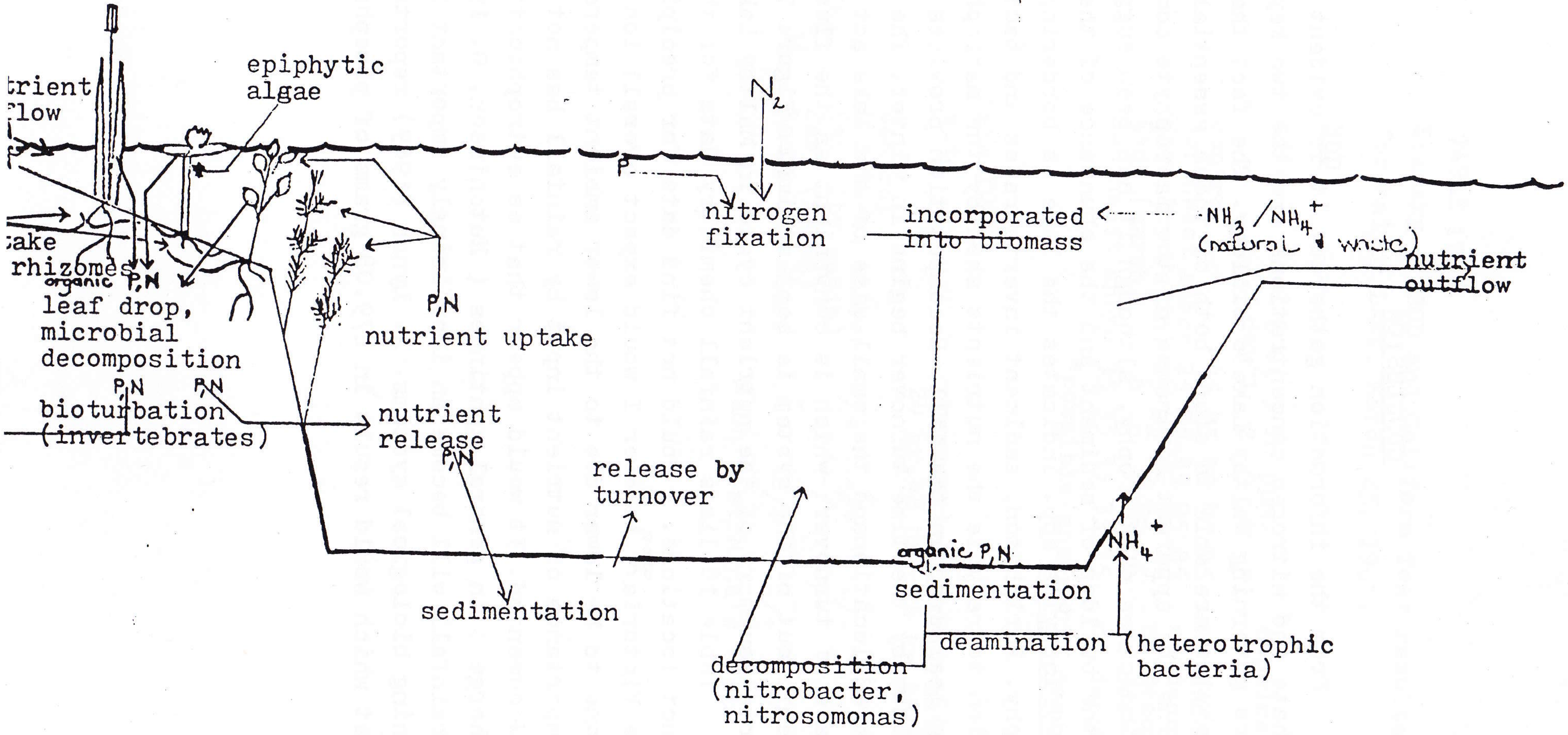

figure 7. Diagram of nutrient (phosphate and nitrogen) flow in Maltby Lake.

TABLE 18

Chemical Analysis of Rainwater (units, mg./1)

ion	U.S.S.R.[1]	Gainesville[2] Florida	Pasadena[3] California
NH_4^+	0.9	0.12	0.60
Na^+	1.5	0.44	0.57
K^+	0.7	0.20	0.08
Mg^{2+}	1.5	0.12	0.08
Ca^{2+}	2.0	0.41	0.19
SO_4^{2-}	9.2	2.05	2.88
Cl^-	2.1	0.98	1.03
NO_3^-	1.3	0.19	4.65*
HCO_3^-	5.6		
pH	6	4.5	4.1
cond.	45		

*high due to auto exhaust/combustion

[1]Nuttonson,M.Y. (1973)

[2]Hendry, C.D. (1980)

[3]Liljestrand, H.M. (1978)

settling into Maltby Lake per year.

Finally, it should be mentioned that the low water nutrient levels but high sediment nutrient levels is characteristic of a system tending towards dystrophy. Dystrophy however implies acidic conditions resulting from impeded drainage and slow decomposition of litter and detritus. This is not the case at Maltby Lake. The levels of humic acids are low and the recycling of nutrients is quite efficient. Thus, one can best describe the lake as mesotrophic; with dominant macrophyte production during the summer resulting in nutrient depletion, followed by dominant cyanophyte, Aphanezomenon sp., activity through the winter.

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IMPACT OF DEVELOPMENT

Figure 7 shows the representative trophic status of Maltby Lake; it is presently mesotrophic, bordering on either dystrophy or eutrophy. A shift towards dystrophy would seem to be the course of natural succession. This would result in the eventual filling in of the lake with sediment (gyttja) and a gradual acidification of the water, especially if Spagnum sp. were to become established. This succession would occur extremely slowly, representing hundreds of years in the lake ontogeny.

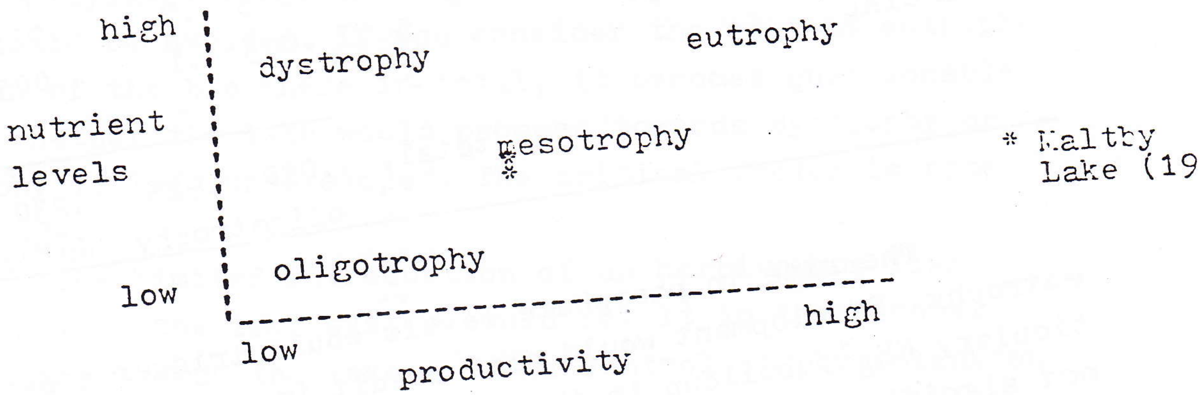

Figure 7. Representative trophic status of Maltby Lake.

If the land around the lake is developed, it is quite likely that phosphate and nitrogen enrichment of the lake would occur. Table 19 summarizes the present and projected nutrient loading of the lake using Uttormark's model (N.Munteanu 1981).

table 19. Nutrient loading statistics, calculated using Uttormark's model.

land use	% of drainage basin present	developed	nutrient loading (kg./ha./yr) before P	N	after development P	N
RESIDENTIAL	5	20	.05	.125	.2	.5
FOREST/PARK	70	50	.035	.7	.025	.5
AGRICULTURAL	5	5	.005	.1	.005	.1
COMMERCIAL	-	5	-	-	-	-
		total,	.090	.925	.230	1.100
			oligotrophy		eutrophy	

The rise in phosphate levels would trigger a shift towards eutrophy. Development would also result in some nitrogen, particulary NH_4^+, buildup in the lake. Phytoplankton growth is not significantly effected by rising NH_4^+ levels (D.Toetz 1981), while macrophyte growth is inhibited (E.Best 1980). The availability of phosphate and the observed toxicity of NH_4^+ to macrophytes would seriously alter the macroflora of Maltby Lake. The result could be a shift in lake biology from a system dominated by macrophyte growth to one dominated by algal growth. A change in the invertebrate and microbial component would also occur. This would not be aesthetically pleasing as the water would be rendered unsuitable for drinking or recreation. This sort of senario can be avoided by careful planning of the development of the lake.

Limiting the development to smaller phases would dilute the effect of eutrophication by spreading the impact of nutrient leaching and soil erosion into the lake over a longer time period. The most important preventative measure would be the use of more efficient sewage treatment technology. If a large number of septic tanks were put into use around the lake, the lake would effectively become the septic field. The use of fertilizers must also be restricted by implimenting restrictive neighborhood covenants or Saanich planning bylaws. Thus, the rapid eutrophication of Maltby Lake could be avoided. If you consider the present eutrophication of the biosphere in total, it becomes questionable as to whether the lake would proceed towards dystrophy or eutrophy if left undeveloped. The critical factor is rate of change.

The limited introduction of an herbivorous fish species into the lake system could result in the removal of nutrients from the lake and the control of phytoplankton growth. It would be advantageous, for gastronomic reasons, if the fish was an edible variety.

Finally, I should point out that the use of a combination of the **strategies** I have suggested to control eutrophication would be the most logical way to insure the preservation of Maltby Lake as a healthy and aesthetically pleasing system. The key to the control of environmental impact is in the management ability of the private and public interests represented in any environmental issue.

Many thanks to Dr. Hagmeier, Nina Munteanu and the rest of the students for their help in the development of this report.

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