THE DECOMPOSER SUBMODEL
OF
MUD LAKE BOG ECOSYSTEM

Grant-in Aid Report
Submitted by:

Robert Bosserman
Carol Forthman
Bruce Leon

August, 1973

TABLE OF CONTENTS

page #

Abstract. The importance of decomposers in ecosystems has not been generally appreciated. The approach used to model the decomposition activity of Mud Lake Bog is to enter it as transfer coefficients of the compartments being decomposed. The structure of the decomposer submodel is analyzed and zonation, as the separation of the chemical reactions in decomposition, is discussed. The model is yet uncomplete because of a lack of time and materials to complete the experimentation, but those experiments performed are discussed. The decomposer submodel compartments are listed with flow rates, and the entire model is diagrammed.

DECOMPOSER SUBMODEL
(Bosserman, Forthman, Leon)

The decomposer compartment can be defined as the part of an ecosystem that accomplishes the breakdown of of dead organic material~~s~~ into its component parts releasing dissolved inorganic and organic substances, and smaller organic particles. In some cases animals that consume detritus can be functionally considered to be decomposers. In this system, however, we have limited our consideration to those organisms (bacteria and fungi) that carry out the decomposition primarily externally and which, in fact, accomplish most of the breakdown of dead organic materials in the system.

The fungi are considered (Harley, 1971) to be the most important organisms in the breakdown of large materials because they possess hyphae that can penetrate the large pieces of plant and animal matter and are not restricted to surfaces as are bacteria. The fungi (and bacteria) absorb nutrients as soluble material. Therefore, they act by secreting substances into their environment that cause the solution of organic molecules. Although much of the material thus broken down is absorbed directly by the microorganisms, some is also released into the surrounding environment and is thereby available to other organisms. Microorganisms also make nutrients available as a result of specialized biochemical pathways. They can accomplish reduction or oxidation of compounds (e.g. N_2 to NH_3 and S_2 to H_2S) using reactions that are unavailable to higher organisms because they lack the proper enzyme systems or are unable to survive the anaerobic and/or reducing conditions necessary for some of the reactions. These characteristics, the ability to break down organic structures and in the process release soluble nutrients, the production of certain compounds that are essential for plant growth but generally unavailable to plants from other sources, and the ability to live and carry on energy-using activities in environments where other organisms are excluded, determine to a large extent the importance of decomposer organisms in the ecosystem.

There are two general approaches available for studying decomposition. The first of these is to characterize the flora and to measure biological activity. The second is to study the products of decomposition. The former method has many difficulties that make good quantification nearly impossible. The techniques for isolating and enumerating all microorganisms are generally unreliable. Direct counts tend to be too high because dead organisms and debris are often included in the count. Furthermore, they cannot distinguish between different types of organisms except on the basis of gross morphological and staining differences which are of little informational value. Plating of microorganisms tends to give low counts because the media almost invariably selects against certain organisms. This problem is especially difficult in the case of anaerobic organisms, because they require special plating techniques. Plating may be suitable for analysis of isolated laboratory preparations and for finding individual groups of organisms, but it is not very useful for describing an entire microbial association and it gives no information on activity other than the relative concentrations of certain organisms.

Measurement of biological activity by studying the the reactions of certain groups of microorganisms in the laboratory can give some indication of the reactions occurring in the field. Unfortunately only the potential rates of activity under specified conditions can be measured which may have little relationship to the field reality.

Because the function of decomposer organisms is breaking down organic structures so that both the organic and inorganic nutrients can be recycled, the activity of microorganisms can be indirectly measured by measuring the rate of production of these end products. This approach has several advantages: 1/ it deals with the problem of relating microbial activity to the rest of the system (e.g. for studying the availability of nutrients) 2/ it obviates the need for dealing directly with microbial populations and all the difficulty attendant upon measuring rates of activity or microbial numbers, 3/ techniques for measuring many of these parameters are readily available 4/ the results, apply directly to the field situation being considered and need not be extrapolated from laboratory experiments.

The foregoing considerations led us to choose the approach of characterizing the breakdown products of decomposition for the Mud Lake Bog model.

Relatively little literature was found that dealt directly with the rates of decomposition or with the substances released by decomposition in peat bogs. The most fruitful direct information was derived from an article by Clymo(1965) in which he describes experiments in which he introduced samples of peat and plant material in mesh litter bags into various layers of peat. After one year he measured the loss of organic material from the bags. He found relative rates of 13:9:2 percent decomposition per year at 0- 10, 6-8, and 75 cm below the surface of the moss. These correspond to an aerobic zone, a zone of fluctuating oxygen levels, and a permanently anaerobic zone. He also found higher rates of decomposition in the moss capitula than in the parts behind the capitula.

Waksman(1932) analysed different layers of several sphagnum peats and found increases in : pH, ether and alcohol soluble fractions and lignins with depth. Hemicelluloses and celluloses decreased with depth and proteins re-

remained approximately stable (% dry wt.).

In general fiber size also decreases with depth(Boelter 1969) indicating that the large organic structures have been broken down to smaller particles in older peat.

Overall it appears that decomposition in bogs occurs as follows:

1/ In the aerobic zone breakdown of large organic structures begins. Water soluble organics and nutrients are released and made available to plants. The organisms responsible for this are probably fungi of many types and heterotrophic bacteria. The numbers and types of organisms are probably greatest in this zone(Waksman, 1932).

2/ As the peat becomes covered with new growth the resulting decrease in oxygen leads to a decrease in numbers and types of organisms present. The rate of decomposition begins to slow down. Compaction begins and fiber size is further reduced.

3/ With an increase of peat cover, anaerobic conditions become permanent. The numbers and types of organisms decreases as well as the rate of decomposition. The accumulation of toxic compounds also restricts activity of all but exceptionally tolerant organisms.

It is in the last two zones that the rate of accumulation exceeds the rate of breakdown so that sediments build up. The organisms present are restricted to certain microbes that can function in these conditions.

Some of the principle organisms found in anaerobic environments and the reactions they are responsible for are:

1/ Sulfur reducing bacteria

$$SO_4^{=} \rightarrow \underset{SH}{S_2} \rightarrow H_2S$$

2/ Denitrifying bacteria

$$\begin{tikzcd} NO_3^-(\text{or}NO_2^-) \arrow[rr] \arrow[dr] & & N_2 \\ & N_2O \arrow[ur] & \end{tikzcd}$$

✓

3/ Nitrogen fixing bacteria

$$N_2 \rightarrow NH_3$$

4/ Methanogenic bacteria

$$CO_2 \rightarrow CH_4$$

(Adapted from Brock 1970)

Not all of these bacteria are necessarily present in bog systems, but they represent the principle categories of microbial activity in anaerobic environments.

Literature Cited

Boelter, D.H. 1969. Physical properties of peat as related to degree of decomposition. Soil Sci. Soc. Am. Proc. Vol.33(4).

Brock, T.D. 1970. Biology of Microorganisms. Prentice-Hall, Inc. Englewood Cliffs, N.J. 737p.

Clymo, R.S. 1965. Experiments on the breakdown of Sphagnum in two bogs. J. Ecol. 53, 747-758.

Harley, J.L. 1971. Fungi in Ecosystems. J. Anim. Ecol. 41, 1-16.

Waksman, S.A. 1932. Chemical composition of peat & the rôle of microorganisms in its formation. In. Scientific Contributions of Selman A. Waksman. Rutgers University Press. New Brunswick, New Jersey. p161-185.

✓

Descriptions of Zones in Submodel (Decomposers)

I Vertical Zonation

A. Mat, Forest + Interface - 3 zones

1) <u>Aerobic</u>

The zone including all above water biomass and that part of the under-water area that contains dissolved oxygen. In most of the bog references in the literature the aerobic zone reaches to between 8-20 cm below the water surface

2.) <u>Anaerobic 1</u>

The zone immediately below the aerobic zone. In this model it is defined as extending down the depth penetrated by live roots.

3) <u>Anaerobic 2</u>

The zone below Anaerobic 1.

B. Lake - 2 zones

1) Lake Water

This zone is the open water above the false bottom. In this study its depth ranged from 1-1.5 m in the center of the lake to less than 50 cm at the edges in the water lily zone.

This zone is considered to be aerobic throughout and potentially capable of maintaining photosynthetic organisms down to & possibly slightly below the water-false-bottom interface during the summer. The lake water is subject to mixing with the sediments which are probably a significant source of nutrients. It also receives runoff from the *Sphagnum* mat and the *Thuja* swamp on the southern boundary of the bog.

2.) False Bottom

The false bottom consists of all interactions within the lake sediments. This zone could be divided into aerobic and anaerobic sections but because there are probably large fluctuations in the extent of aerobic conditions throughout the year (due to mixing with lake waters), this was not done. Instead, the aerobic and anaerobic reactions were considered in the same compartments and conceived of as fluctuating in relative importance with seasonal changes.

II Horizontal Zonation

1) Forest

The area of the bog having significant cover of spruce and tamarac that is the outermost zone of study and probably the oldest in terms of succession.

2. Mat "MOSAIC"

An area of open mat having only occassional and generally small trees. The vegetation is primarily a *Carex*-*Sphagnum* mat with many small clumps of low bushes often with small trees in the center.

3) Lake-Mat Interface.

The zone from the edge of the open mat to the lake side edge of the Nymphaea area of the lake. This area includes a "ridge" of spruce + tamarac trees just inside of a floating sedge mat. The floating mat is primarily Carex sp with alder, Chamaedaphne and other small shrubs + herbs present. On the lake side of this mat is an area of especially shallow water with many water lilies (Nymphaea) which has been included in this zone.

In drawing up the interaction matrix between the Mat and the Lake-Mat interface we have ignored reactions occurring solely in the Nymphaea zone because they are essentially lake reactions and therefore not part of the interface as far as the decomposer compartment is concerned.

4) Lake

The open water area interior to the water lily zone. Generally about 1-1.5 m of clearwater over flocculant sediments called false bottom.

METHODS OF SAMPLING AND ANALYSIS -- DECOMPOSER SUBMODEL

Many of the methods of sampling and analysis used in the construction of the bog model are not explained ~~x~~ in the documentations of the flows. In order to make the results of these experiments available, the methods and their results are listed below. Adequacy of sampling and the accuracy of the results are also discussed.

Water Samples

Water samples were collected in all four zones and brought back to the lab for analysis. In the forest and the mosaic, subsurface water samplers were installed at 0.5 and 1.0 m below the surface of the mat. ~~in~~ These consisted of ~~length~~ lengths of PVC pipe with a piece of fine screening attached over one end to keep out large particulate matter. Tin cans were inverted over the protruding ends of the pipes to prevent contamination by rain. Surface samples were collected by pressing a bottle into the surface of the mat, ~~an~~ and all subsurfaces samples were taken up with a hand vacuum pump. Rain and leachate samples were taken ~~x~~ by placing collecting vessels under spruce and larch trees and Chamaedaphne bushes and in the open. Samples were collected during the rain spell to avoid effects of evaporation.

In general samples were taken only once although a few were repeated in the field and in the lab for comparison of results and to evaluate the effects of short-term storage, particularly on P. Obviously, repeated sampling and a greater number of sample sites would have been preferable but time constraints prevented this.

The following analyses were made on water samples:

Phosphorus — Dissolved inorganic phosphate (orthophosphate) was measured using the Hach colorimeter method both in the field and in the lab. No differences were found between field and lab tests so it was considered adequate to bring samples in for testing. Highly colored samples were run at full concentration and at dilutions to discover possible interference with the test. The diluted samples gave results consistent with the full strength samples. The results in general showed decreasing values from forest - transition- lake - mat. The samples of leached water showed values higher than rain. Full details of this project and the results are given in the project report on P (Barbara Caggiano).

Nitrogen — Dissolved nitrates, nitrites and ammonia were measured using the Hach colorimeter methods. Details of methods and results are given in the project report on N(Daniel Goldberger).

Calcium and Magnesium — These ions were measured using the Hach Kit titration method. This method reads only to the nearest 5 ppm. Nevertheless the large differences in values among the various zones demonstrate the different types of environment involved. The lake and transition have considerably more free Ca and Mg than the forest or the mosaic. This is reflected in the different pH regimes in the areas and is largely due to the very high cation exchange capacity of peats. Since the C.E.C. is high in the peat mat areas the free Ca and Mg are not a good indication of the available Ca and Mg. Exchangeable (adsorbed) ions are available for use by plants and the algae, [illegible] and Mg is [illegible] these ions are [illegible] limiting.

The values for Ca and Mg are listed below:

[illegible] Mud Lake Bog (Summer 1973) [illegible]
(accurate to the nearest 5ppm)

SITE	Ca	Mg
Forest : surface	35	5
0.5m	10	5
1.0m	45	15
Mosaic: surface	5	0
0.5m	10	5
1.0m	10	0
Lake: surface	55	45
0.5m	70	35
1.0m	65	40
Rain	0	0
Chamaedaphne leachate	10	0
Spruce leachate	10	0
Larch leachate	5	5

Potassium — Potassium was run on the atomic absorption spectrophotometer on filtered samples. This represents only free K; some additional K may be available as exchangeable ions on peat. The values obtained are listed below:

Values of Potassium in Mud Lake Bog (Summer 1973) in ppm

SITE	K
Forest: surface	2.83
0.5m	----
1.0m	2.83
Mosaic: surface	1.42
0.5m	1.46, 1.58 (two samples)
1.0m	0.91
Lake: surface	----
1.0m	---- 0.60
false bottom	0.36
Rain	0.40, 0.50 (two samples)
Leaf leachate:	
Chamaedaphne	1.50
Spruce	1.42
Larch	2.67

Peat and [illegible] false bottom sampling

Originally, small diameter corers were tried for use in taking peat samples but it was found that they would not take cores in fibrous peat. Two different corers were then constructed: 1) a one-pound coffee can was cut at one end to produce a saw-toothed edge and was used to take ~~ant~~ surface cores. 2) Thin sheet metal (stove piping) was then made into a longer, saw-edged cylinder of similar diameter for deeper cores. These brought up cores with little compaction or deformation. False bottom samples were obtained by hand pumping with a vacuum pump.

Analysis for ~~p~~ P content was run by dry ashing peat samples, taking up the ash in acid and running the neutralized extract on the Hach colorimeter for orthophosphate. Results and discussion are in the project report on P (Barbara Coggiano).

Peat ~~s~~ was analyzed for fiber content and bulk density.

Rationale for fiber size experiment

1) "Physical properties of peat as related to degree of decomposition" by D.H. Boelter.
2) Particle size and structure depend on the degree of decomposition
3) fibers are defined as particles larger than 0.1mm
4) as decomposition occurs fibers become smaller

Objectives

1) ~~try~~ to determine relative rates of decomposition in a peat column
2) to determine the rate at which peat accumulates

Sampling

1) taken with stove pipe sampler
2) taken in the [illegible] layer at the edge of [illegible] the bog
   a) *Chamaedaphne*, *Sphagnum* sp and blueberry association
   [illegible]

[illegible]

3) abrupt change in peat characteristics 15-16 cm down
   - a) above 15-16 cm is *Sphagnum* and *Carex* peat
   - b) below 15-16 cm is tightly packed material composed of very small particles

Procedure

1) core refrigerated until used to inhibit decomposition

2) layers corresponding to peat depths were taken from the core

3) % dry weight
   - a) 1/2 of the peat layer was weighed, oven dried and re-weighed
   - b) the amount of water held was measured
   - c) % dry weight determined (used in calculations below)

4) Wet sieve technique
   - a) 1/2 of the peat layer was weighed and soaked in Calgon (5% solution) for 12-20 hours
   - b) run through nested sieves with a gentle stream of water Sieves: #10 - 2.00mm; #18 - 1.00mm; #35 - 500microns; #60 - 250 microns; #140 - 105 microns
   - c) peat particles on each sieve were collected, filtered
   - d) the collected particles were oven dried and weighed
   - e) the weight of the different sized particles present were compared to the total dry weight

Results

1) Dating peat layers
   - a) qualitative observations
     - 1) below 15-16 cm
       - a/ tightly packed smaller materials
       - b/ tiny pieces of wood throughout
     - 2) above 15-16 cm
       - a/ loosely packed and fibrous
       - b/ *Sphagnum*, *Chamaedaphne*
   - b) this layer must be the level where the fire occurred
   - c) fire occurred in 1916
   - d) accumulation rate of 0.26 cm/yr

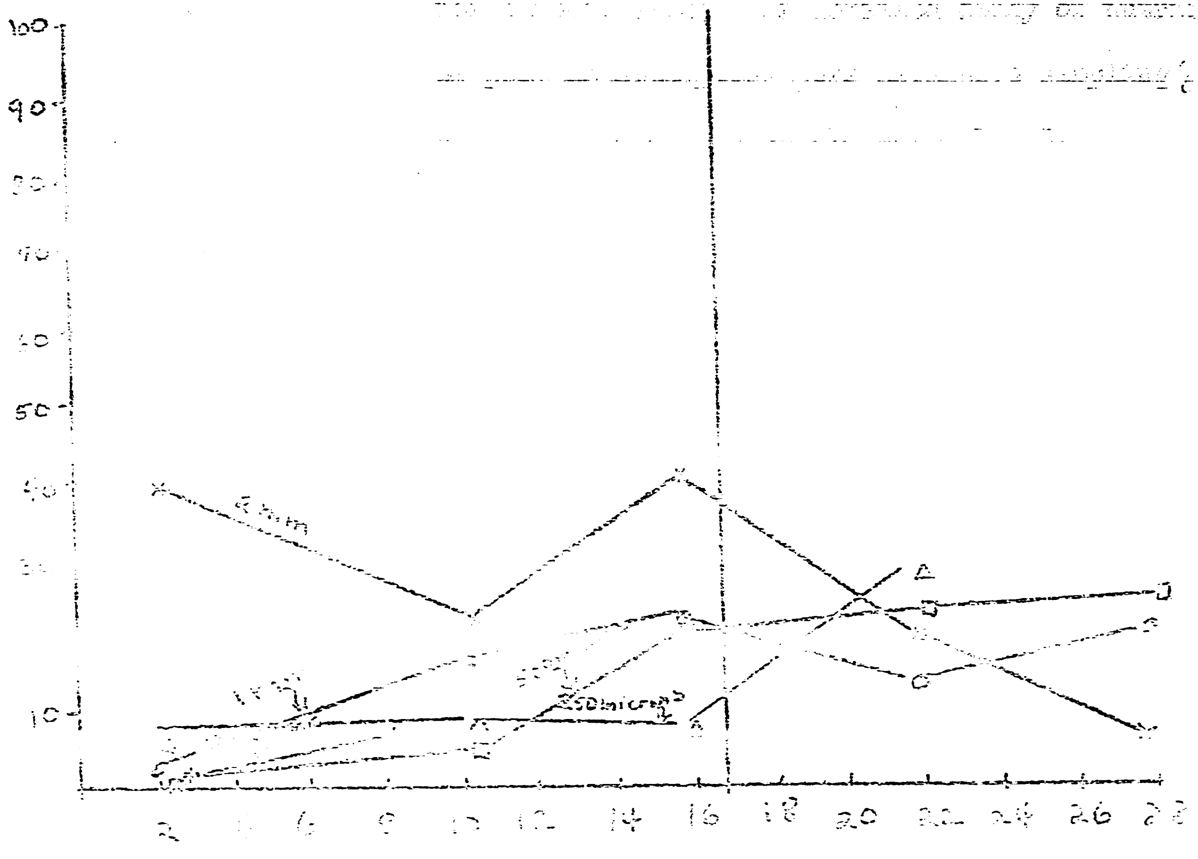
2) Fiber content
   - a) Table I and Graph II give the percentage of various fiber sizes found at different depths
   - b) progressive decrease in amount of fibers larger than 2mm with depth
     - 1) except at depth of ≈ 15-16 where a quantity of *Chamaedaphne* [illegible]
     - 2) amounts of all other fiber sizes remained with depth or decreased slightly
     - 3) therefore the amount of smaller fibers increased with depth
   - c) sharp distinction between characteristics of peat above 15-16 and below 15-16 cm
     - 1) above 15-16 cm ; 53-54% of dry weight is fibers

epth	2mm % wt	1mm % wt	500 microns % wt	250 microns % wt	105 microns % wt
0-4	39	2.9	3.7	5.9	3.9
9-12	18.7	14	6.5	8.4	5.2
15-16	35	19	19	6.7	—
21-22	15	12	22	23	—
28	5	19	20	—	—

% TOTAL FIBER CONTENT

Depth	> .1 mm	> .5 mm
0-4	54.4	45.6
9-12	53.2	32.2
15-16	79.7	63
21-22	72 +	49
28	44 +	44

TABLE I



Gr [illegible]

    2) below 15-16 cm 44-79% of dry weight is fiber
    3) fibers less than 250 microns but greater than 105 microns could not be collected in the samples below 15-16 cm

d) relative amounts of decomposition in the Sphagnum, Chamaedaphne peat cannot be determined
    1) depth is not great enough
    2) not enough samples run

Conclusion

1) In 57 years peat has accumulated 15-16 cm an average of .264 cm yr^{-1}

2) Amounts of smaller fibers increases with depth in peat

Plant Samples

Samples were taken from several plant species in the bog and analyzed for P content. The method used was the same as the one used to test peat samples. Details are in the P project report (Barbara & Coggiano).

In general the sampling techniques suffered ~~far~~ from the following problems 1) non-randomness 2) lack of replication. Nevertheless relative values for different zones were obtained and can be used as starting points for further study. If detailed study of nutrients and physical properties of peat is attempted, more extensive sampling and in some cases better analysis techniques should be employed.

Implementation of the Mud Lake Bog model required some changes in the conceptual, 120-compartment, 4-zone model which we had developed. What was needed was a clear-cut objective, much simplification, and mounds of data. The objective emerged: a successional model which would show all of the zones passing by in order. The simplification was minimal- some lumping, some elimination of compartments. The amount of data needed was staggering. We collected as much as we could, looked up some and made up the rest. But the model structure is basically sound, and the numbers can be updated.

Table 1 shows the flows into the four compartments AERDOM, ANDOM, POM, and PH in all four zones, as well as their flows out of the system. Table 2 includes their standing quantities as well as experimental data. The values are of four types: experimentally determined, deductively determined from experimental data, adapted from the literature, and arbitrary. In general, the standing quantities are based on experimental findings, some of the flows are literature values, and the rest are arbitrary. These sources are given for each value in Table 1.

Experiments of the decomposer subgroup included the mapping of pH values, location of the top of the anaerobic peat zone, dissolved oxygen measurements, determination of the bulk density of peat, DOM (dissolved organic matter), and POM (particulate organic matter), and assessing the quantities of calcium and magnesium in water samples. pH was determined by the extraction of water samples from many points in the study area (lake and mat) and direct measurement of pH in the field with a portable Beckman meter. Samples were taken at depths of 0, 0.5, and 1.0 meter and position was taken by triangulation. The results are in Map 1. For the model, average values of pH 8.5, 6.8, 3.7, and 4.7 were chosen for the lake, transition, mat, and forest zones respectively; these are surface pH values.

The location of the top of the anaerobic peat-aerobic peat interface was a challenge in experimental design. It was reasoned that H_2S, produced by respiration of anaerobic sulfate-reducing bacteria, was mostly consumed by aerobic bacteria at the interface or held in bubbles and solution in the anaerobic zone; H_2S is not very water-soluble. In addition, H_2S is chemically active and can be detected easily. Therefore, we expected to see the effects of H_2S at the beginning of the anaerobic zone. The first experiment invloved extracting water samples from different depths in the mat and adding concentrated $CuSO_4$ solution; a black precipitate should have resulted for concentrations as low as 1 part per million; none did. This finding was contrary to observation, since the peat when freshly dug, smells of H_2S at as shallow a depth as 20 cm. The second test was the Hach kit method: a piece of $Pb(C_2H_3O_2)_2$ soaked filter paper treated with the water sample bubbled with Alka-Seltzer. No positive results resulted from this test. The third test was similar: a meter stick with a $Pb(C_2H_3O_2)_2$ -soaked filter paper strip, 50cm long, was inserted into the mat and allowed to stay overnight. No discoloration appeared. The fourth method was the only successful one, and it was a copper wire stuck in the mat a month before it was pulled out; the black sulfide appeared 19 cm below the mat surface, with the aerobic zone shown as a scoured-clean section of wire. Two factors had apparently not been considered: 1) the sample must not be extracted, since H_2S volatilizes from water solution; and 2) the probe must be left in long enough to become sufficiently treated.

Dissolved oxygen tests were unreliable in the mat because the anaerobic samples become aerated by the process of extraction. The lowest DO measured, at a meter depth and with the greatest precautions, was 1.5 ppm; most were higher, regardless of depth. The method used was the Winkler method. Above the anaerobic zone, the method was more suitable, and the DO's used in the model represent the average oxygen concentration in grams per square meter for the anaerobic zones.

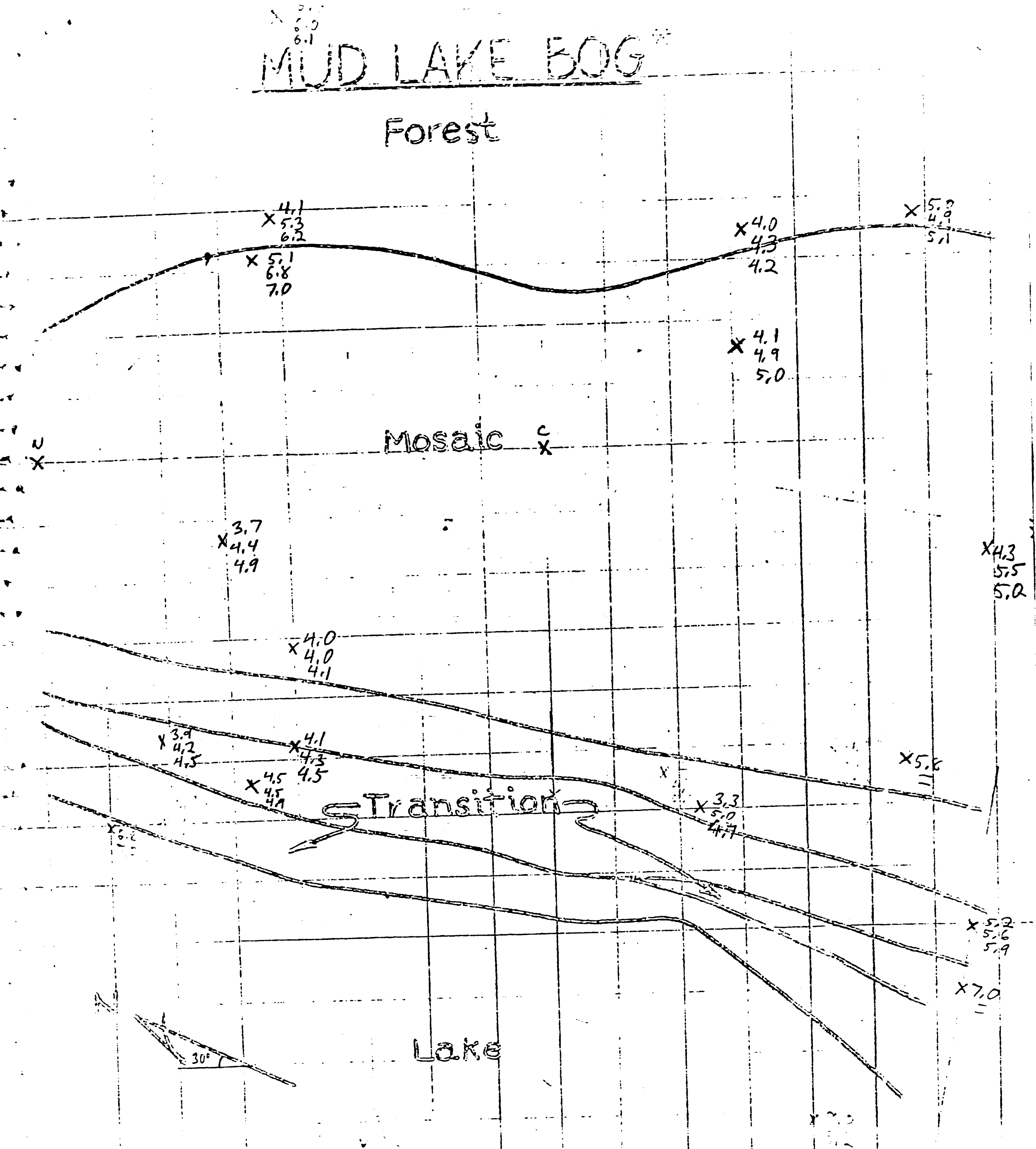
Bulk density of peat was determined by taking several corings of known volumes of peat from the mat surface, squeezing out the water, and successively filtering the water to a filter pore size of .45 microns, the defined limit of dissolved to particulate organic matter. The dry weights of the peat samples were averaged together to get the standing quantity of peat used in the model; the two repititions were very close. <u>Sphagnum</u> on the surface of the mat was subtracted in the model. The filtered water was dried, then ashed at 425°C to give the Dissolved Organic Matter content and the non-ashed total nutrient content. The results of these two experiments are given in Table 2.

Calcium and magnesium values were determined using Hach kit methods in the laboratory on water samples previously collected and stored in a refrigerator. Titrations were accurate within five parts per million by weight. The model values are a weighted average, using the quantities found in each zone and the size of that zone.

The flows which were not experimentally determined are documented in Table 1. Water flow through the bog was assumed to carry soluble matter with it from the system, and since the rainfall input was known (77cm/yr) many flow rates were derived using simple equilibrium conditions of what gets removed must be replaced in a steady-state. Other values were adapted from the Lake Texoma Cove model(1974), Clymo(1964), and Reader and Stewart(1972). Arbitrary values are either outright guesses (based on a little intuition)or were guessed to balance the flow of inputs and outputs of the compartments.

The model is now in the process of being debugged and run, and results will be available soon for comparison to actual data.

MUD LAKE BOG



SCALE: 1 SQUARE = 100 M^2

[illegible] area for Systems Ecology, Summer, 1978

Copyright 1978

[illegible]	AERDOM	8.712	7.[illegible]		
[illegible]TER		.52 Lake Texoma			
[illegible]			2.18[illegible]		
[illegible]INV			.0214		
[illegible]ETINV		6.13	1.423		
[illegible]VRT		2.92			
FISH			3.805		
ZOOPL		53.056	53.785		
[illegible]RPEAT			.0027 (L. Texoma)	.0027 (L. Texoma)	.0027 (Lake Texoma)
[illegible]		.000422 (L. Texoma)	.000504 (L. Texoma)		
DO		23. (Lake Texoma)	13. (Lake Texoma)	.13 (Lake Texoma)	13. (Lake Texoma)
AERDOM	ANDOM	1.299 (1)	.385 (Arbitrary)	1.8 (Arbitrary)	3.273 (Arbitrary)
ANPEAT			.001 (Reader & Steward)	.0004 (Reader & Steward)	.00021 (Reader & Steward)
POM		5×10^{-5} (Arbitrary)			
PHPL	POM	78.	88.459		
[illegible]ALGAE			112.937		
[illegible]ITTER		5.2 (Lake Texoma)	45.230		
[illegible]			2.164		
[illegible]NINV			.0214		
DETINV		.613	19.28		
[illegible]-VRT			1.49		
AQVRT		2.92	2.93		
FISH			3.805		
[illegible]PL		53.056	53.765		
[illegible]		23. (Lake Texoma)	23. (Lake Texoma)		
[illegible]LGM	PH			7.5×10^{-3} (2)	7.5×10^{-3} (2)
Forcings	PH	(g/m²/yr dry wt.) 3.192×10^{-4} (1)	7.54×10^{-6} (1)		
[illegible]	Losses	(/yr)	.025 (Arbitrary)	.406 (Arbitrary)	.406 (Arbitrary)
[illegible]			.00119 (Arbitrary)	[illegible] (Arbitrary)	.040 [illegible]
[illegible]			.002341 (Arbitrary)		
		4.4[illegible] (1)	.6[illegible]4 (1)	[illegible] (1)	1.[illegible] (1)

(1) [illegible] rainfall data; assuming that the outflow contains as many g/m² as there [illegible] compartment. All forcings are [illegible] water input.

(2) Based on equilibrium assumptions of pH being replenished at the same rate as its loss by water flow.

SUMMARY OF FLOWS INTO NUTRIENT COMPARTMENTS

	LAKE				TRANSITION				MOSAIC				FOREST			
↓ TO →	P	N	K	CA MG	P	N	K	CA MG	P	N	K	CA MG	P	N	K	CA MG
NVIRONMENT	2×10^{-4}		4×10^{-3}		2×10^{-4}		4×10^{-3}		2×10^{-4}		4×10^{-3}		2×10^{-4}		4×10^{-3}	
TREES	—	—	—	—	—	—	—	—	8×10^{-5}		1.4×10^{-4}		8×10^{-5}		1.4×10^{-4}	
TLITTER	—	—	—	—	—	—	—	—	8×10^{-3}	0.16	1.1×10^{-2}		1.1×10^{-2}	2.7×10^{-2}	4×10^{-2}	
ALITTER	3.2×10^{-2}	8.6×10^{-2}			3.2×10^{-2}	8.6×10^{-2}			—	—	—	—	—	—	—	—
PLARTH	—	—	—	—												
DETINV		8,03				8,03				8.03				8,03		
PLINV	—	—	—	—		1,33				1.33				1,33		
CRNINV	—	—	—	—		4.68				4,68				4,68		
AQURT		1,28				1,28			—	—	—	—	—	—	—	—
FISH		3,25				3,25			—	—	—	—	—	—	—	—
ZOOPL	0,44	11.3			0,44	11.3			—	—	—	—	—	—	—	—
ARPEAT	—	—	—	—	9×10^{-7}	2.5×10^{-5}	8×10^{-5}	3×10^{-5}	9×10^{-7}	2.5×10^{-5}	8×10^{-5}	3×10^{-5}	9×10^{-7}	2.5×10^{-5}	8×10^{-5}	3×10^{-5}
AERDOM	.665	3.25×10^{-3}	1×10^{-2}	4×10^{-3}	.665	3.25×10^{-3}	1×10^{-2}	4×10^{-3}	.665	3.25×10^{-3}	1×10^{-2}	4×10^{-3}	.665	3.25×10^{-3}	1×10^{-2}	4×10^{-3}
ANDOM	1.5×10^{-2}	2.3×10^{-3}	7.2×10^{-3}	2.7×10^{-3}	1.5×10^{-2}	2.3×10^{-3}	7.2×10^{-3}	2.7×10^{-3}	—	—	—	—	—	—	—	—
POM	3.4×10^{-4}	5×10^{-6}	1.5×10^{-5}	7×10^{-5}	1.5×10^{-5}	5×10^{-6}	1.5×10^{-5}	7×10^{-5}	—	—	—	—	—	—	—	—

NOTE: 1) Flows are in rates (coefficients) & are multiplied by the biomass of the Donor compartment to give fluxes = g m^{-2} yr^{-1}

2) A dash means no flow exists.

A blank means a flow is possible but no number is available.

Table 2. Experimental Data on Peat and DOM

Volume of peat core = 1.021 l = 1.021×10^{-3} m³.

Weight of dried peat samples = 32.94 g
34.46 g

average 33.70 g

Density of Peat + Live Sphagnum = 3.3×10^4 g/m³.

	Mat	Lake
Filtrate Residue, Dried	.1209 g	.0548 g
Ashed	.0716 g	.0324 g
Part lost in Ashing = [DOM]	.0493 g	.0224 g
Error	±.005 g	±.01 g
Volume of sample	1.021 l	.780 l
Density of DOM	48.3 g/m³	28.7 g/m³

Volume of Lake Sample = .780 l = 7.80×10^{-4} m³

Weight of dried POM = 24.03 g

Density of POM (1 m depth in Lake) = 3.08 g/m³

Compartment	Lake	Transition	Mat	Forest	
AERDOM	2872	21	9.6	9.6	(g/m²)
ANLDOM	200	[illegible]	[illegible]	[illegible]	
POM	140,[illegible]	12[illegible]			
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	

DOCUMENTATION OF NUTRIENT COEFFICIENTS

The flow rates used in the model are listed on the following charts. Where no flow ~~xxx~~ exists into a nutrient compartment there is a dash(—_) and where there is probably a flow but no numbers could be gotten there is a blank space. A flux rate to a nutrient from a compartment is equal to the coefficient number (flow rate) listed here multiplied by the biomass of the donor compartment. All fluxes are in $gm^{-2}yr^{-1}$. The zones to which the flows apply are listed as (L=lake, T = transition, M = mosaic, F = forest)

TO P

from ZOOPL (L,T)

The Lake Texoma model used flow coefficients of $0.004 wk^{-1}$ ($0.208 yr^{-1}$) and $0.013 wk^{-1}$ ($0.676 yr^{-1}$) for small and large zooplankton respectively. The relative proportions of small and large zooplankton in the lake were not known so the figures were arbitrarily averaged to give a flow coefficient of $0.44 yr^{-1}$.

from LITTER (M,F) (%P x %decomposition/yr)

= The % P in litter was taken from literature values (Small, 1972) These were 0.031 for the mosaic and 0.047 for the forest. The rates of decomposition were from Reader and Stewart (1972) and were 0.27 for the mosaic and 0.243 for the forest.

from ALITTER (L,T) (%P x %decomposition/yr)

The % P was determined experimentally for water lilies (0.12) The % decomposition was arbitrarily [illegible] from the value for LITTER in the mosaic.

from [illegible] (F) arbitrary

[illegible]

TO P (cont.)

from ARPEAT (T,M,F) (% P x % decomposition/yr)

The percent P in peat was taken from Buckman and Brady (1969) (0.99%) and the % decomposition of peat was taken from Reader and Stewart (1972), as 0.1%.

from AERDOM (L,T,M,F) (as above)

Taken from the flow rate in the Lake Texoma model, 0.665 yr^{-1}.

from ANDOM (L,T) arbitrary

from POM (L,T) arbitrary

from ENVIRONMENT (rain) (L,M,T,F) g/l measured experimentally

TO N

from ZOOPL (L,T) (see P for functions)

flow coefficient taken from ~~x~~ the Lake Texoma model

from TLITTER (M,F)

The % N values were taken from Small (1972): Mosaic 0.58; Forest 0.11. The % decomposition was taken from Reader and Stewart (as given for P)

from ALITTER (L,T)
The % N were taken from literature values for Potamogeton sp. in Gerloff and Krombholz (1966): 3.2%..The % decomposition was arbitrarily taken as equal to the mosaic TLITTER rate.

from DETRIT (L,S,M,F,T)

0.35 (arbitrary value for % N) multiplied by the respirationrate 229.5.

from PLINV (T,M,F) Respiration rate = 3.80

from [illegible] (L,M,F) Respiration rate = 13.38

from [illegible] (L,T) Respiration rate = 3.65

from FISH (L,T) Respiration rate = 9.28

from [illegible] (L,M,F)
The % N was taken from Buckman and Brady (1969) as 2.5%. The % decomposition was taken from Reader and Stewart as 0.1%.

TO N cont.

from AERDOM (L,T,M,F) arbitrary

from ANDOM (L,T) arbitrary

from POM (L,T) arbitrary

TO K

from TLITTER (M,F) (see P for functions)
The % K is from Small (1972): Mosaic = 4.2%; Forest = 4.7%. The Percent decomposition was taken from Reader and Stewart(1972): Mosaic = 27%; Forest = 24.3 ~~%~~ %.

from TREES (M,F) arbitrary

from ARPEAT (M,F)
The % K is from Buckman and Brady (1969):0.08%; and the decomposition rate is from Reader and Stewart(1972): 0.1%.

from AERDOM (L,T,M,F)
The % K is arbitrarily assumed to be ~~xxxx~~ equal to peat; the % decomposition is arbitrary.

from ANDOM (L,T) arbitrary

from POM (L,T) arbitrary

from ENVIRONMENT (rain) (L,M,F,T) The g/l were measured experimentally.

TO CAMG

from ARPEAT (T,M,F)
The % CAMG was taken from Buckman and Brady (1969): 2.0%; and the % decomposition was from Reader and Stewart(1972): 0.1%.

from AERDOM (L,T,M,F,)
The % CAMG assumed equal to peat, the % decomposition was arbitrary.

from ANDOM (L,T)
The % CAMG was assumed to be the same as peat; the % decomposition was arbitrary.

from POM (L,T)
The % CAMG was from Wakeman (1938) for [illegible] under peats: 2.8%; the % decomposition was arbitrary.

[illegible]

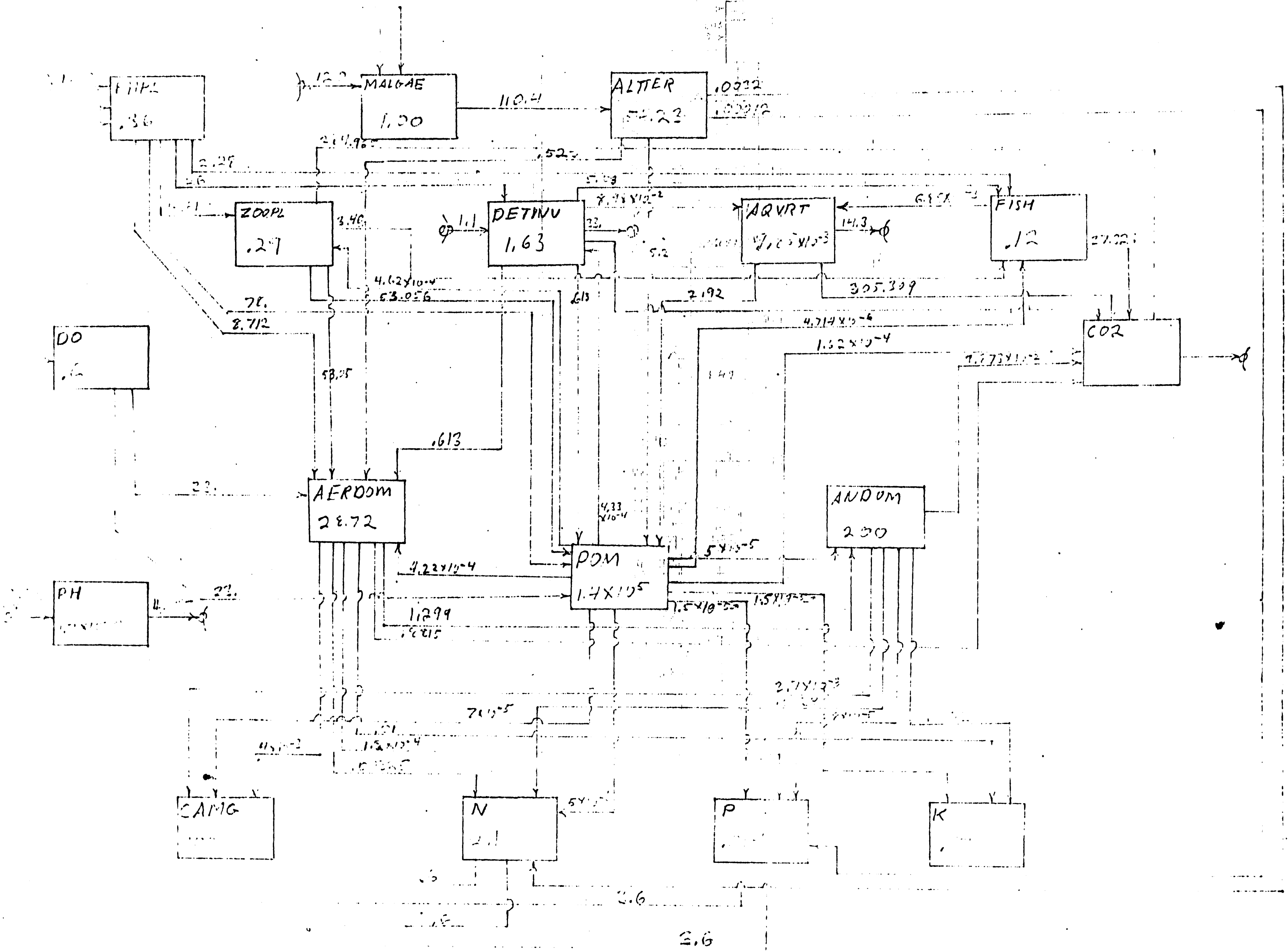
THE "PHYCOMYCETOUS" FUNGI OF [illegible] AND LAKE [illegible]

Reported by the students of Bot. 480, [illegible] and R.L. Shaffer
U.M.B.S. JULY 12, 1973

The following list gives a qualitative estimate of the relative abundance of the fungi isolated and identified:

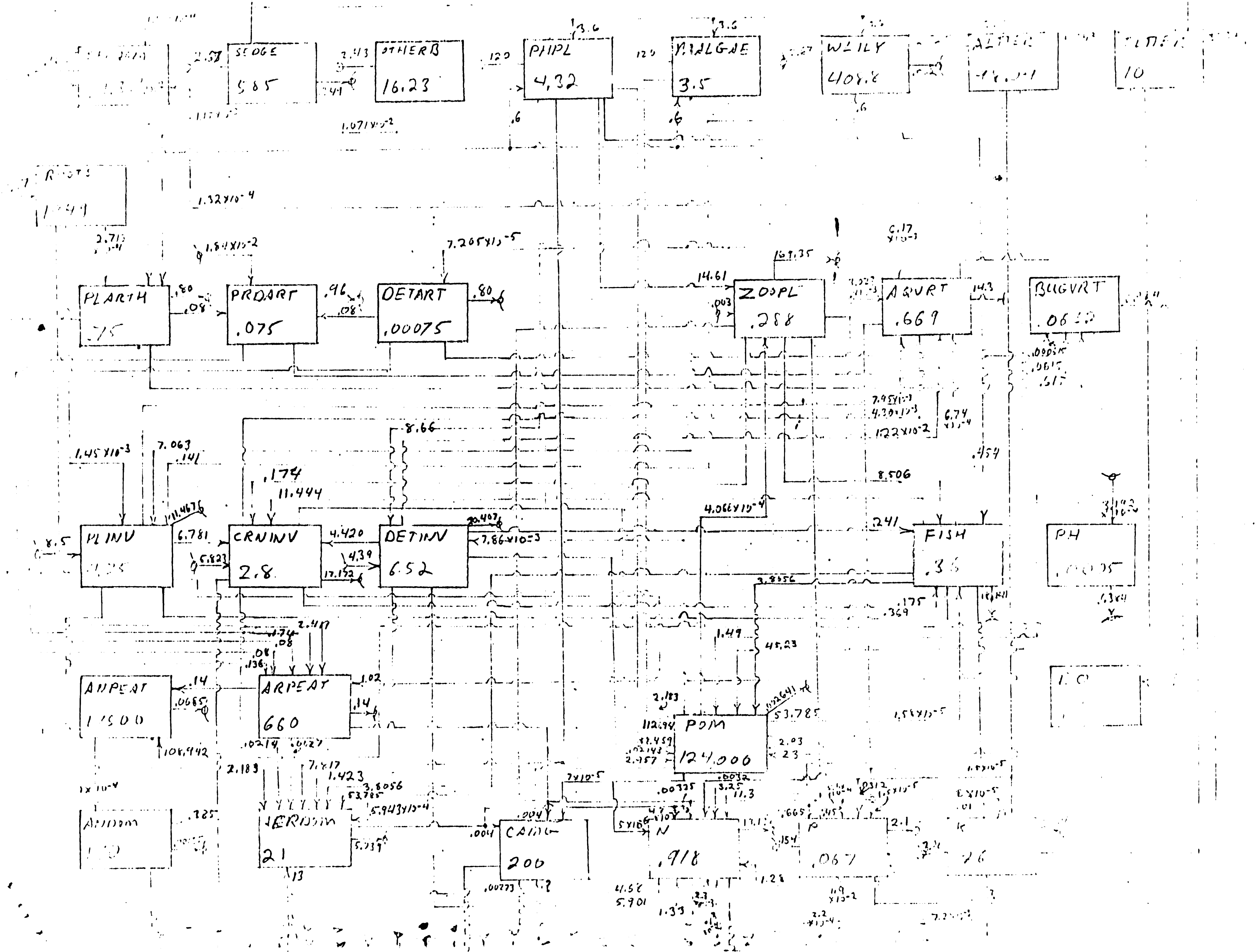
FUNGI	ABUNDANCE
Allomyces sp. (highly doubtful)	+1
Blyttiomyces helicus	+1
Ectrogella monostroma	+1
Endochytrium ramosum	+1
Entophlyctis aurea	+1
1 Mucor grisseo-lilacinus	+1
Mucos hiemalis	+3
Mucor vallesiacus	+3
Nowakowskiella sp.	+2
Olpidium luxurians	+2
Olpidium pendulum	+4
Phlyctidium mycetophagum	+2
Phlyctochytrium bisporosum	+2
Phlyctochytrium papillatum	+1
Rhizidium ramosum	+1
Rhizophydium chitinophilum	+2
Rhizophydium bullatum	+2
Rhizophydium keratinophilum	+2
Rhizophydium sphaerotheca	+5
Saprolegnia sp.	+4
Septosperma anomalum	+2
Septosperma rhizophydii	+2
Zygorhizidium moelleri	+2
Zygorhynchus sp.	+2

Note:
+1 = single occurrence; very scattered
+2 = present in small numbers; scattered or uniform
+3 = a rank assigned to two species of Mucor (a soil fungus) found in abundance on the petri plate soil isolations
+4 = very abundant
+5 = ubiquitous; occurring in all cultures at all times



[illegible] boxes, in g/m³ (by weight)

[illegible] Diagram, [illegible]


SEDGE
5.85
OTHERB
16.23
PHPL
4.32
MALGAE
3.5
WLILY
408.8
10
PLARTH
.75
PROART
.075
DETART
.00075
ZOOPL
.288
AQVRT
.669
BUGVRT
PLINV
CRNINV
2.8
DETINV
6.52
FISH
.36
PH
ANPEAT
1500
ARPEAT
660
VERDOM
21
CAINC
200
POM
124,000
N
.918
P
.067
2.57
2.43
1.071×10⁻²
120
3.6
.6
1.32×10⁻⁴
2.71
1.84×10⁻²
7.205×10⁻⁵
.80
.08
.96
14.61
161.35
.003
14.3
6.17×10⁻³
7.95×10⁻³
4.30×10⁻³
1.22×10⁻²
6.74×10⁻⁴
.454
8.506
8.66
1.45×10⁻³
7.063
.141
11.4676
.174
11.444
6.781
5.823
4.420
4.39
17.152
20.407
7.86×10⁻³
4.066×10⁻⁴
.241
3.8556
.175
.369
8.5
1.49
45.23
2.41
.74
.08
.136
.14
.0685
1.02
106.942
.10214
.0127
2.183
7.417
1.423
3.8056
53.785
5.943×10⁻⁴
5.939
.225
1×10⁻⁴
13
.004
.00273
7×10⁻⁵
.00725
.0032
3.25
11.3
5×10⁻⁶
2.03
23
112.94
2.457
53.785
1.28
4.56
5.901
1.33
.665
.154
2.1
1.55×10⁻⁵
2.2
1.9×10⁻²

LITERATURE CITED

1) Buckman, D. an Brady, R. 1969. TheNature and Properties of Soils. TThe Macmillan Co. Ltd., London

2) Clymo, R. S. 1964. The origin of acidity in Sphagnum Bogs. The Bryologist 67(4):427-431.

3) Gerloff, G. C. and P. H. Kromholz. 1966. Tissue analysis as a measure of nutrient availability for growth. Limnology and Oceanography 11:529-537.

4) Reader, R. J. and J. M. Stewart. 1972. The relationship between net primary productivity and accumulation for a peatland in southeastern Manitoba. Ecology 53(6):1027-1037.

5) Small, Ernest. 1972, Photosynthetic rates in relation to nitrogen recycling as an adaptation to nutrient deficiency in peat bog plants. Canadian Journal of Botany. 50:2227-2233.

6) Waksman, S. A. 1932. Chemical composition of peat and the role of microorganisms in its formation. In, Scientific Contributions of Selman A. Waksman. Rutgers University Press. New Brunswick, New Jersey. pp 161-185.