Eastern Deciduous Forest Biome
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MICRODYNAMICS OF DETRITUS FORMATION AND DECOMPOSITION AND ITS ROLE AS A STABILIZATION INFLUENCE IN FRESHWATER LAKES

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INTRODUCTION

Studies during the past year (Fall 1974-Fall 1975) on the micro-dynamics of detritus formation and decomposition have shown that there are distinctive differences between Lake George macrophytes with respect to sloughing and mortality, and that the allochthonous and autochthonous detritus that enters the sediment system is decomposed throughout the winter at rates dependent upon temperature and chemical composition of the organic material.

I. DETRITUS FORMATION

One of the major aquatic producers in Lake George are the rooted aquatic plants found in the littoral areas around the lake (Sheldon and Boylen, 1973, 1975) and the sublittoral macro-alga Nitella flexilis (Stross, 1972). During the first year of study of detritus formation in Lake George, initial decomposition rates of several primary producers within this ecosystem were determined. These included 4 rooted macrophytes, the macro-alga, Nitella flexilis, and a mixture of terrestrial deciduous leaves from the surrounding watershed. Nearly 60 species of rooted aquatic macrophytes are known to occur in the littoral zone of Lake George ranging from 1 to 9 m (Ogden, et al., 1975). The four chosen for initial study, Najas flexilis, Potamogeton amplifolius, P. robbinsii, and Vallisneria americana, have been shown to be among the most productive of this diverse group of plants (Boylen and Sheldon, 1973; Sheldon and Boylen, 1975). The vegetation of the lake drainage basin is composed predominantly of hemlock, sugar and red maple, white pine, and northern oak (Nicholson and Scott, 1972). Although amounts are not known at present, the contribution of leaf and woody material during autumn defoliation to the annual nutrient budget of the lake through detritus formation should be significant. Data on decomposition rates of these various materials, release of N, P, and C, and microbial colonization are presented in this report.

Methodology

Aquatic plants were collected in August, 1974 while they were still in a productive state. Samples were handled quickly to minimize metabolic trauma. Plants were shaken and gently blotted to remove excess water and 10 g wet weight of each was placed in nylon mesh bags of 2 pore sizes, 200μ and 3 mm diameter. Bagged plants were attached to a wooded frame suspended in the water 1 m below the surface at Smith Bay, Lake George. Winter sampling was facilitated by the use of an aeration bubbling system which prevented the area from freezing. Terrestrial leaves were collected soon after autumn defoliation and bagged in a similar manner. All bags were placed in the lake and samples removed for analysis at intervals from August, 1974 through May, 1975. Dry weight to wet weight curves were established for each plant material to allow the dry weights of 0 time samples to be calculated. At each sampling time 4 samples of each material were removed from the water; 2 were used to determine loss in dry weight and 2 were subsequently homogenized and used for chemical and microbiological assays.

Results and Discussion

Percent loss of dry weight in both autochthonous and allochthonous producers are presented in Table 1. Considerable differences exist in the decomposition rates of the aquatic rooted macrophytes ranging from 8 weeks for total decomposition (to particle sizes less than 200μ) of Najas flexilis to 34 weeks for no significant decomposition of P. robbinsii. P. amplifolius maintained 0 time biomass from August through the winter. At ice off (34 weeks) plants began a rapid decline in biomass. Unfortunately, these were the final samples of P. amplifolius to be withdrawn from the lake, and, therefore, we are unable at this time, to conclude that this species remains undecomposed during the winter but is quickly decomposed during spring warming. The macro-alga, Nitella flexilis, lost considerable dry weight (31%) within 2 weeks after containment. Further loss was gradual with 48% remaining after 15 weeks; thereafter the

Table 1

Percent loss of dry weight in autochthonous and allochthonous primary producers[a,b]

ELAPSED WEEKS	WATER TEMPERATURE	ROOTED MACROPHYTES				MACRO ALGA	ALLOCHTHONOUS
		N. flexilis	V. americana	P. emplifolius	P. robbinsii	Nitella flexilis	Terrestrial leaves
0	24	0	0	0	0	0	0
2	22	18.9	1.9	0	0	31.1	17.6
		12.0	34.7	0	0		
4	18	25.5	29.4	2.6	20.3	--	--
		13.3	41.7	0	7.4		
6	15	88.7	26.8	0	0.4	44.0	13.3
		90.0	51.0	0	0		
8	13	99.0	47.5	19.7	--	--	--
		99.0	78.0	--	--		
10	11		53.8	4.7	13.8	--	--
			77.2	17.9	0		
12	9		88.2	--	--	44.4	20.2
			81.0	--	--		
15	5		94.9	21.9	0	51.7	11.4
			88.5	18.8	0		
20	3			29.6	0	--	11.4
				0	0		
24	2			0	0	—	—
				0	0		
28	2			52	0	94.5	—
				0	0		
30	2			0	--	99	12.3
				0	--		
34	8			46	6.5		—
				46	2.0		

[a]Macrophytes were contained in two sizes of mesh bags. The first number for each sampling time refers to duplicate determinations of plants in 200 μ diameter mesh bags: the second, determinations of plants in 3 mm diameter mesh bags. Nitella flexilis and terrigeneous leaves were contained in 200 μ diameter mesh bags only.

[b]0 = a determination with no loss in biomass

-- = no sample taken

blank = material completely decomposed; sampling completed.

decomposition rate increased so that after 30 weeks 99% of the initial weight was degraded. Allochthonous leaves lost little more than 10% of their initial dry weight for the entire sampling period of 34 weeks. Experimental studies for 1975-1976 will center around the degradation of allochthonous materials in the lake and nutrient release.

Samples were originally placed in bags of 2 mesh sizes to observe the possible participation of macro-invertebrates in the fragmentation and decomposition of the plants. Such participation has been shown to occur in more productive ecosystems (Fenchel, 1970). In each case the macrophytes decomposed at similar rates regardless of the pore size of the mesh bags. A record of the macro-invertebrates found associated with the decomposing plant samples is given in Table 2. There appears neither an association between mesh size and invertebrate number nor between invertebrate numbers and the rate of decomposition of a particular plant species. The most common macro-invertebrates found were amphipods of the genus Gammarus. This genus is most numerous in the littoral zone water column (McNaught, et al., 1972). The participation of protozoa and micro-invertebrates in the decomposition process will be studied during 1975-1976.

The loss of total phosphorus and Kjeldahl nitrogen from the 4 macrophytes is shown in Table 3. Analysis of nitrate nitrogen is in progress to allow calculations of total nitrogen. With each species, release of N and P follow rates similar to those observed for decomposition (Table 1). Bacterial colony counts were made on each species with enumerations determined at 4°C and 24°C. All plating were performed on nutrient agar from suitable dilutions of plant homogenates. Results are presented in Table 4. Colony forming units (CFU) at zero time reflect the bacterial component of the epiphytic community and are similar for each of the species ranging from 2×10^7 to 2×10^8 CFU/mg dry weight of plant material. Counts increase per mg dry weight on Najas flexilis, P. amplifolius and V. americana. Plates incubated at 25°C had higher

Table 2

Number of Macroinvertebrates on Decomposing Leaf Samples[a,b]

DATE	ELAPSED WEEKS	ROOTED MACROPHYTES N.flexilis 200μ	N.flexilis 3mm	V. americana 200μ	V. americana 3mm	P.amplifolius 200μ	P.amplifolius 3mm	P.robbinsii 200μ	P.robbinsii 3mm	MACRO-ALGA Nitella flexilis 200μ	ALLOCHTHONOUS TERRESTRIAL LEAVES 200μ
8/29/74	0	0	0	0	0	0	0	0	0	-	-
10/8/74	6	0	0	0	0	10	0	0	0	-	-
11/5/74	10			2	3	2	1	0	5	0	0
11/22/74	12			1	0	0	0	0	0	-	-
12/11/74	15			0	0	2	0	0	1	0	10
1/15/75	20					0	0	1	0	1	0
2/13/75	24					2	3	2	3	6	0
3/13/75	28					1	0	0	1	0	0
4/22/75	34					0	1	0	1	0	0

a
0 = absence of macroinvertebrates
- = sample not taken
blank = sample decomposed

b
Most macro-invertebrates were amphipods of the genus gammarus.

Table 3

Nitrogen and Phosphorus Content of Decomposing Macrophytes[a,b]

Elapsed Weeks	N. flexilis		V. americana		P. amplifolius		P. robbinsii	
	N	P	N	P	N	P	N	P
0	33.8	2.91	23.6	1.81	6.5	0.55	11.1	0.60
2	16.9	1.49	18.4	1.00	7.9	0.46	11.0	0.61
4	12.1	0.40	17.1	1.05	6.8	0.63	11.2	0.82
6	5.9	0.13	12.4	0.65	7.2	0.45	7.7	0.99
8	0.0	0.0	8.3	0.39	--	--	--	--
10			8.6	0.43	11.8	0.58	9.8	0.75
12			6.6	0.25	--	--	--	--
15			0.0	0.0	11.5	0.66	8.8	0.78
20					10.1	0.88	11.0	0.75
24					7.1	0.45	8.9	0.76
28					8.3	0.73	8.2	0.89
34					4.2	0.31	9.2	0.61

[a]Nitrogen values represent Kjeldahl-N/g dry weight of 0 time samples.

[b]Phosphorus values represent total phosphorus/g dry weight of 0 time samples.

Table 4

Bacterial Colony Counts of Decomposing Aquatic Plant Material[a,b]

Elapsed Weeks	N.flexilis		V.americana		P.amplifoluis		P.robbinsii	
	4C	24C	4C	24C	4C	24C	4C	24C
0		1.9×10^{8}		1.8×10^{8}		1.9×10^{7}		3.5×10^{7}
2	4.4×10^{7}	1.7×10^{8}	4.2×10^{6}	1.4×10^{8}				
4	6.7×10^{7}	1.3×10^{9}	7.5×10^{6}	1.0×10^{9}	2.8×10^{6}	1.9×10^{8}	4.5×10^{7}	1.3×10^{8}
6	4.0×10^{8}	2.5×10^{9}	1.9×10^{8}	2.8×10^{8}	1.2×10^{7}	1.8×10^{8}	2.3×10^{7}	9.5×10^{7}
8			8.5×10^{8}	2.3×10^{9}				
10			3.8×10^{8}	7.6×10^{8}	6.5×10^{7}	3.5×10^{8}	4.8×10^{6}	2.0×10^{8}
12			2.2×10^{9}	2.5×10^{9}				
15					9.3×10^{7}	8.0×10^{8}	5.1×10^{6}	5.2×10^{7}
20					1.1×10^{8}	1.9×10^{9}	4.5×10^{7}	7.3×10^{7}
24					1.8×10^{7}	3.2×10^{8}	4.0×10^{7}	5.9×10^{7}
28					3.2×10^{7}	4.6×10^{8}	6.9×10^{6}	8.9×10^{7}

a
Data expressed as total colony forming units/mg dry wt of plant material

b
Incubations carried out at 4 and 24C.

counts than those incubated at 4°C. Colony morphologies were similar in all cases; however, species identifications were not made. P. robbinsii which remained productive throughout the winter and spring ice-off maintained a status quo microbial population. It is not known if species composition changes as the water temperature approached with winter low of 2°C. In only one instance (colonization of V. americana) did the total counts at 4°C incubation increase faster than those at 24°C until the two were approximately equal, suggesting that such changes in populations do occur. Attempts to show cellulase activity by microflora were not successful.

Macrophyte beds were recognized to be an important part of the shallow-water ecosystem, especially as a source of detritus. However, the only existing macrophyte submodel was the one developed to simulate Myriophyllum spicatum at Lake Wingra, Wisconsin (Titus, et al., 1972); unfortunately, it represents neither the growth forms nor the phenology of the diverse species at Lake George.

Therefore, a new, general macrophyte submodel, of simpler structure but with more elegant phenologic functionalities, was developed. Functions include morphological changes influenced by depth, variations in fruiting habits, overwintering productivity, and sediment preference. The submodel is capable of simulating both sloughing and die-back in diverse species under a variety of conditions. It is currently being parameterized and evaluated for four representative species (Potomogeton amplifolius, P. robbinsii, Vallisneria americana, and Najas flexilis) at several sampling stations in Lake George. A more detailed description of the submodel has been published (Scavia, et al., 1975).

II. DETRITUS DECOMPOSITION

In a study of organic carbon in sediments of Lake George, Schoettle and Friedman (16) have reported on the distribution of organic carbon and the interrelationship existing between lake bottom morphology

and clay and organic content. In general, the clay and organic matter content rises as one goes toward the deeper sections of the lake where fine particulate matter can accumulate without disturbance from wave and current action, and where the rates of decomposition are slower because of the permanently cold water.

The organic material found in those deep sections of the lake that are removed from the shore is truly detrital in the sense that no recognizable origins of the material can be determined by visual examination. In contrast the organic material found in sediments adjacent to the shoreline (deep as well as shallow) are found to contain tree bark, twigs, leaves and needles in various stages of decomposition. Sediments from the macrophyte beds found in numerous bays surrounding the lake (Boylen and Sheldon, 1973) show a large component of macrophyte fragments as well. These recognizable components of the organic fraction of the sediment vary considerably as a function of time of year and temperature of the sediment. Studies already described under "detritus formation" quantify this annual occurrence.

Although the organic component of the lake bed of Lake George in general varies from 0.1% in sandy areas to 10% in deep sections and areas adjacent to stream outflows, marshes, shoreline and macrophyte beds, levels much higher than 10% are frequently found in highly productive bays. Although the ability to recognize leaves, macrophyte fragments, etc. changes considerably as decomposition advances, the total organic component of the sediment has been found to change only slightly as a function of time over the course of a year with the exception of sampling sites very close to concentrated sources of plant debris and detrital carbon (e.g., marshland, shoreline, etc.) (Clesceri and Daze, 1975).

Since organic material is clearly being converted, it was obvious that the microbiological flora were actively involved in chemical oxidations and that one should be able to follow this activity by means of monitoring changes in the polymeric composition of the organic material.

Thus although total organic composition may not appear to vary greatly, the composition of the organic material (and the energy content) would reflect these microbiological activities.

It had been previously shown (Clesceri and Dazé, 1973) that the sediments associated with macrophyte beds exhibit substantial glucose assimilatory activity especially from late June to late August and that this activity is highly correlated (0.739) with the deoxyribonucleic acid (DNA) component of richly organic sediments (Clesceri and Dazé, 1975).

Thus a study of the changes in key organic polymers was made both in situ and in the laboratory at 4°C and 25°C with sediment collected in November from a dense Nitella flexilis bed. In addition, an in situ study was made with sediment collected from the delta of a small stream. This delta contained no plant cover and was used to compare autochthonous and allochthonous contributions.

To begin to appreciate the relative importance of particulate organic carbon contribution from the tributaries of Lake George, a preliminary study was made of three brooks with respect to total organic carbon and DNA contributions.

The relationship between the plant cover and the sediment microflora is of course synergistic in that inorganic nutrients are made available to the plant through microbial decomposition and mineral mobilization of the organics produced by the growing as well as the dying plant. This relationship can perhaps be best seen by studying the mineral mobilization capacity of the sediment in the absence of plant cover. When plant cover is present these nutrients are immediately assimilated and one sees an apparently static situation. This aspect of detritus decomposition was touched upon through examination of the interstitial water levels of sediment associated with plant cover as well as by early laboratory mineral mobilization studies which are being continued into the present project year.

Finally, a simulation model for microbial decomposition in the pelagic zone of Lake George was developed and coupled to an existing lake

ecosystem model (Park, et al., 1975) in order to simulate cycling of carbon, nitrogen, phosphorus and oxygen in the pelagic zone. The original structure of the decomposition submodel given by Clesceri, et al. (1972) changes significantly during the course of the project year, following the conceptual model of Wetzel, et al. (1972). It was assumed that decomposition occurs in two separate microenvironments within the pelagic portion of a lake: in the water itself and on suspended detritus. The water environment contains labile dissolved organic matter, refractory dissolved organic matter, and unattached decomposers. The detrital microenvironment consists of particulate organic matter, sorbed dissolved organic matter, and attached decomposers. Each of these groups is simulated in the model (Fig. 1).

The inorganic forms of carbon, dissolved oxygen, nitrogen (ammonia and nitrate), and phosphorus (orthophosphate) are modelled as pools largely resulting from and subject to biological processes.

The revised submodel exhibits good fits to observed data from Lake George. It is described further in Bloomfield, et al. (1975), Bloomfield (1975), and Clesceri and Bloomfield (1976).

A profundal model, that includes sediment decomposition, has been implemented, but has not been tested fully. It is currently being incorporated in a two-layer model that represents stratified (including anoxic) conditions.

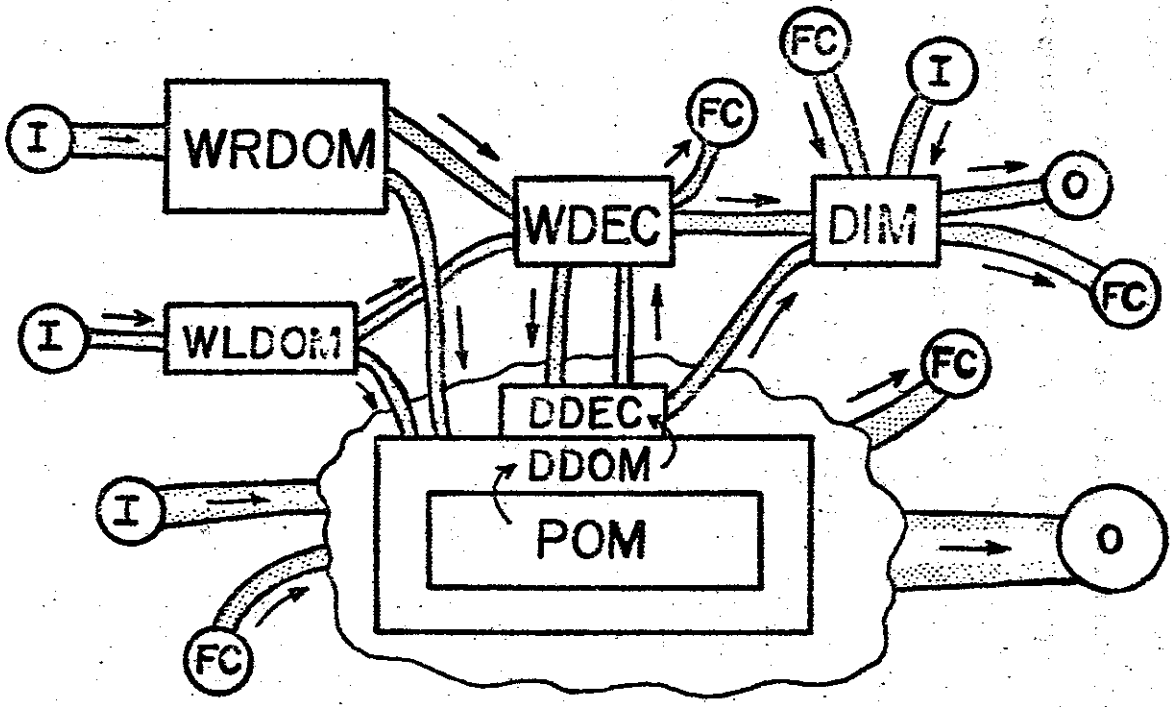
Material and Methods

a. In situ polymer study

Sediment samples were taken from two sites within the Nitella bed in Smith Bay (northern basin eastern shore) on November 19, 1974 with an Ekman dredge. One site was located near the northern shore of the bay at a depth of 11 meters and the other site was located near the southern shore at a depth of 13 meters. At the time of sampling the water temperature was 10°C and the air temperature 11°C. The samples were placed in one liter plastic containers upon removal.

FIGURE 1

MAJOR MASS TRANSFERS IN THE PELAGIC ZONE DETRITAL CHAIN



FC - CONNECTION WITH FOOD CHAIN.

I - INPUTS FROM LAND, ATMOSPHERE, LITTORAL ZONE AND BOTTOM SEDIMENT.

O - LOSSES TO ATMOSPHERE AND BOTTOM SEDIMENT.

On shore, three containers from one site were mixed together in a 3.0 liter beaker. Visible algal material was removed with tweezers. Fifty ml were measured out (± 5%) and transferred either to a small polyethylene bag (Playtex baby bottle liner) or to a sack made from dialysis tubing (Fisher Separapore: 12-14,000 molecular weight exclusion). The plastic bags and dialysis sacks were tied with polyester thread.

These bags were placed in a nylon sleeve which was fastened at both ends with nylon twine and attached to a 2 inch dowel rod weighted at both ends with concrete molds. The system was placed back into the bay at the northern end of the Fresh Water Institute dock and sampled at intervals throughout the winter and spring.

A similar system was prepared with sediment that was autoclaved for a control.

In addition to the Nitella system, a ediment sample taken from the mouth of a creek running into Smith Bay was processed as above for comparison between allochthonous and autochthonous influenced sediments. This sediment was a mixture of clay, gravelly-type sand and organic mud containing pine needles in contrast to the Nitella mud.

Again, a control system was prepared.

Samples were analyzed in November, January, March, May (two times) and June (two times) for the following constituents in duplicate:

1. Dry weight of a standard slurry made with distilled water was determined.
2. Organic weight of the standard slurry was subsequently made by combusting the dry weight samples at 600°C. No carbonates have been found in these sediments thus there is no danger of carbonate interference in measuring the organic weight by difference.
3. DNA was measured by the method of Burton (1955) and modified for use on lake sediments.
4. Cellulose was determined using an extraction method developed by Updegraff (1969) and modified for use on lake sediments.

5. Pectin levels were measured by means of a pectin esterase assay (Duel and Stutz, 1958).
6. Lignin was measured by estimating phenol content with tungsto-phosphoric and molybdo-phosphoric acids according to standard methods (13th edition).

b. Laboratory polymer study

Sediment was gathered with an Ekman dredge from Smith Bay in mid-November at 10 meters from a dying Nitella bed. Lake water was also sampled just above the flocculent layer from nearby. The water temperature was 10°C. The sediment was taken to the laboratory for processing. One hundred ml of sediment were placed in each of twelve wide-mouth, 250 ml erlenmeyer flasks and overlain with lake water to the top of the flask. These were tightly stoppered; six were placed at four degrees, the other six at 25 degrees. All were in the dark. At various times up to 35 days the incubation in one flask from each set was stopped and the battery of analyses as above plus hemicellulose (Updegraff) was performed, as they were on a zero-time sample. The water was decanted, millipore filtered (0.45 micron) and frozen for future chemical analysis.

c. Allochthonous input study

Samples were taken in March (once), April (four times) and May (once) to estimate the organic content and the DNA content of the particulate matter entering the lake from West Brook, Northwest Bay Brook and Hague Brook during spring run-off. The current was measured and total discharge can be calculated, but at this time these data are not available. They will be utilized in a later data analysis.

Dry weight, organic weight and DNA were determined as indicated above.

d. N and P levels of interstitial water, column water and sediment

Samples of the sediment and adjacent water column were gathered in June from Warner Bay, Heart's Bay and Harris Bay. Water column

samples were millipore filtered (0.45 micron). Sediment interstitial water samples were prepared by centrifugation and subsequent millipore filtering. Sediment samples for analysis were prepared by resuspending the pellet from the interstitial water centrifugation in distilled water.

Standard procedures were used to analyze water and sediment for pH and alkalinity. Ammonia-N and Kjeldahl-N were determined on an auto-analyzer. Total phosphorus was determined by iso-butanol extraction and dissolved organic carbon was determined by infra-red analysis. Dry weights and organic weights were determined as above.

Results and Discussion

a. In situ polymer study

In the field study of polymer decomposition, we have seen that there is a fairly rapid decrease in cellulose, pectin, and lignin. This was shown both in the bags of cellulose acetate (dialysis tubing), and in those of polyethylene that were filled with either sediment from a bed of Nitella flexilis or a stream delta. In all cases the plant structural components showed a gradual decrease in level during the period late autumn to spring (see Table 5 and 6).

Higher initial levels of cellulose and lignin in the delta sediment are observed. Pectin seems to be quite significant in the Nitella sediment samples, but surprisingly not found in the delta sediments. A significant difference in pH was observed between the polyethylene bags and the cellulose acetate bags. After two months the pH in the polyethylene bags dropped about 1 unit and after 8 months, a drop of 3 units to pH 3.8 was measured. The cellulose acetate bags began to show evidence of deterioration in June and were essentially completely deteriorated by the end of July. This probably explains the increase in the cellulose level in June in the Nitella bags. It is postulated that this is not seen in the delta bags because the cellulose present in the sediment was still relatively high in that system in early June.

The DNA levels seem to indicate microbial cycling and succession

Table 5

Polymer Decomposition (in situ) in Nitella Sediment*

Date	Days incub.	Temp °C	DNA/ 100 mg dry	DNA/ 100 mg org.	Cel/ 100 mg dry	Cel/ 100 mg org.	Pec/ 100 mg dry	Pec/ 100 mg org.	Lig/ 100 mg dry	Lig/ 100 mg org.
11-19-74	0	10.0	0.180	1.563	0.553	4.801	--	--	.047	.408
1-09-75	51	3.0	0.258	2.323	1.111	10.011	0.088	0.790	.035	.315
3-03-75	104	4.0	0.094	1.691	0.275	4.966	0.065	1.217	.027	.492
4-08-75	140	4.0	0.130	1.950	0.208	3.120	0.041	0.615	.020	.300
5-01-75	163	8.0	0.273	2.316	0.180	1.526	0.033	0.280	.012	.091
5-15-75	177	10.0	0.065	0.857	0.077	1.016	0.014	0.185	.027	.354
6-02-75	195	19.0	0	0	0.106	0.987	0	0	.022	.205
6-16-75	209	18.0	0.222	0.809	0.211	1.719	0	0	.055	.448

* from dialysis bags, north site

Table 6

Polymer Decomposition (*in situ*) in Delta Sediment*

Date	Days incub.	Temp °C	DNA/ 100 mg dry	DNA/ 100 mg org	Cel/ 100 mg dry	Cel/ 100 mg org	Pec/ 100 mg dry	Pec/ 100 mg org	Lig/ 100 mg dry	Lig/ 100 mg org
1-09-75	0	3.0	0.241	1.412	1.949	11.435	0.003	0.019	.375	2.20
3-03-75	53	4.0	0.263	1.454	2.147	11.860	0.0	0.0	.370	2.07
4-08-75	89	4.0	0.024	0.153	1.255	8.000	0	0	.322	2.05
5-01-75	112	8.0	0.776	3.535	1.037	4.726	--	--	.085	.387
5-15-75	126	10.0	0.296	1.242	0.476	2.000	--	--	.135	.567
6-02-75	144	19.0	0.085	0.331	0.470	1.826	--	--	.076	.295
6-16-75	158	18.0	0.133	0.708	0.220	1.172	--	--	.067	.357

* from dialysis bags

as levels alternately reach low and high points throughout the incubation. The cycling appears to be a function of length of confinement.

Samples gathered the following spring from the same sites in triplicate showed that there was little change in the composition of the sediment that was not confined in the bags. No doubt this reflects the sedimentation of additional detrital material and reflects the dynamic character of the sediment system.

b. Laboratory polymer study

The changes in organic polymers were also examined over a short interval (34 days) in laboratory studies at two different temperatures. Substantial changes were found to occur as shown in Table 7. Also observed in the laboratory were concomitant increases in the DNA content of the sediment. These paralleled very closely the change in cellulose concentration. It is believed that the cellulose decomposition pattern is representative of other fairly readily degraded bonds since the increase in DNA cannot be accounted for by the cellulose decomposition alone. The initial rate of pectin disappearance exceeded that of cellulose (especially at 4°), but leveled off sooner (See Table 8). Hemicellulose underwent extensive degradation in a fairly linear manner for 13-20 days and then reached a plateau. The lignin values are based upon phenol content making the assay quite nonspecific. Even so, these levels were less than one-tenth of the other parameters measured. The 34 day value illustrates the biodegradability of the material at 25°C. Lignin seems to have a greater temperature coefficient than the other polymers studied.

A preliminary inspection of the supernatants from these incubations show no increase in dissolved organic carbon. No soluble phosphorus or nitrogen appeared until after 13 days of incubation. This corresponds very well with the DNA data which means that during the period of active growth no phosphorus or nitrogen is released to the overlying water. Once the readily degradable material is exhausted, release of phosphorus

Table 7

Organic Compounds Measured in Batch Incubations of Decomposing Lake George Sediment

	Time incub.	Dry wt.	Org.wt.	% Org. /dry	mg DNA g dry	mg cell g dry	mg pectin g dry	mg lignin g dry	mg hemicel g dry	pH
4°	0	3.8740	0.3221	8.5	0.585	9.30	6.45	0.30	---	6.77
	8 hr.	2.9682	0.3009	10.1	0.679	8.70	5.47	0.28	---	6.77
	24 hr.	2.8167	0.2651	9.4	0.831	8.69	4.93	0.29	5.72	6.76
	6 day	3.2239	0.2425	7.5	0.627	8.82	4.62	0.27	4.68	6.52
	13 day	3.0121	0.2750	9.1	1.305	3.26	4.58	0.26	3.40	6.35
	21 day	3.0844	0.2946	9.6	1.313	3.47	4.47	0.22	2.22	6.22
	35 day	3.2146	0.2348	7.3	1.195	2.87	4.40	0.25	2.25	6.21
	% Orig.	---	---	85.9	204.3	30.9	68.2	83.3	39.3*	
25°	0	3.8740	0.3221	8.5	0.585	9.30	6.45	0.30	---	6.77
	8 hr.	3.8260	0.3043	10.0	0.630	7.90	5.81	0.30	---	6.68
	24 hr.	2.8593	0.2581	9.0	0.675	7.54	5.09	0.29	5.64	6.65
	6 day	1.8414	0.2132	11.6	1.168	7.36	5.02	0.28	4.29	6.40
	13 day	1.8468	0.2305	12.5	2.041	2.03	4.35	0.25	3.25	6.35
	21 day	2.4468	0.2477	10.1	1.786	1.65	4.32	0.17	3.52	6.30
	35 day	2.0675	0.2409	11.7	2.046	1.55	4.25	0.12	2.92	6.25
	% Orig.	---	---	137.6	349.7	16.7	65.9	40.0	51.8*	

* Over 34 days

LEGEND:
Dry wt. = dry weight
Org. wt. = organic weight
% Org./dry = percent organic matter
mg cell = cellulose
mg hemicel = hemicellulose

Table 8
First-order Rate Coefficients of Selected Organic Compounds Measured In Batch Incubations of Decomposing Lake George Sediment

		First-order rate coefficients ($days^{-1}$)					
	T (days)	Korg	Kdna	Kcell	Kpect	Klig	Khc
4°	0.33	.523	.452	-.202	-.499	-.209	M
	0.67	-.107	.302	-.002	-.155	.052	M
	5.00	-.045	-.056	.003	-.013	-.014	-.040
	7.00	.028	.105	-.142	-.001	-.005	-.046
	8.00	.007	.001	.008	-.003	-.021	-.053
	14.00	-.020	-.007	-.014	-.001	.009	.001
25°	0.33	.492	.225	-.494	-.317	.000	-.114*
	0.67	-.157	.103	-.070	-.197	-.051	-.051*
	5.00	.051	.110	-.005	-.003	-.007	-.055
	7.00	.011	.080	-.184	-.020	-.016	-.040
	8.00	-.027	-.017	-.026	-.001	-.048	.010
	14.00	.011	.034	-.004	-.001	-.087	-.013

* estimated

LEGEND:

T = Time
Korg = Organic content rate
Kdna = DNA rate
Kcell = Cellulose rate
Kpect = Pectin rate
Klig = Lignin rate
Khc = Hemicellulose rate

and nitrogen occurs since it is then in excess supply for the small amount of microbial or predator biomass that is being synthesized.

c. Allochthonous inputs

The data from this study are presented in Table 9. One obvious conclusion from these data is that the organic content of the particulate load to the lake from its tributaries is very high. Also a relatively large portion of it is biomass as indicated by the DNA levels (range 0.1-3.4% DNA).

d. N, P, and C levels in interstitial water, overlaying water and associated sediment

These data are seen in Table 10. In the sediment, one sees a very high organic content at one meter in Warner Bay. This has been seen in previous studies and is caused by the input from the adjacent marshland. In the water, one sees a roughly ten-fold higher level in nitrogen and phosphorus values in the interstitial water when compared to the overlaying water. This brings up the interesting point of what happens when the sediments are disturbed by currents, wind action, benthos, bottom feeders, etc. How fast and to what extent are these nutrients released to the overlaying waters, and how fast is a new equilibrium reestablished? This question will be addressed in the current project year. The mobilization of minerals is being studied in the current project year in the laboratory as well. Studies are being made to determine the influence of temperature and agitation on the release of C, N and P.

Conclusion

Studies on the formation, deposition and subsequent decomposition of detrital material in fresh waters are expected to elucidate the role of detritus in influencing nutrient levels and biological response in the aquatic ecosystem. The importance of detritus in stabilizing the seasonal nutrient flux in lake ecosystems is hypothesized and is being tested through modeling the dynamics of microbial decomposition and nutrient cycling in Lake George.

Table 9

Allochthonous Particulate Inputs from Three Brooks

Date	Site	mg dry wgt cu. ft.	mg org wgt cu. ft.	% Organics in Particulates	mg DNA g org wgt
3-14-75	Westbrook	0.60	0.40	67.0	34.9
3-21-75	"	--	--	--	--
4-05-75	"	0.37	0.09	24.4	12.2
4-12-75	"	0.54	0.38	70.5	10.8
4-19-75	"	4.33	1.55	35.9	1.7
4-26-75	"	4.88	1.00	20.5	2.0
5-03-75	"	7.61	0.50	6.6	7.2
4-05-75	Northwest Bay Brook	0.19	0.06	31.5	1.4
4-19-75	"	1.68	0.94	56.0	2.2
4-26-75	"	0.27	0.21	78.0	--
4-05-75	Hague Brook	0.61	0.20	32.9	1.7
4-12-75	"	0.85	0.56	66.0	4.2
4-19-75	"	3.08	1.00	32.5	3.9
4-26-75	"	3.65	1.00	27.4	4.2
5-03-75	"	0.66	0.50	76.0	4.4

Table 10

Water and Sediment Chemistry

Interstitial Water

Date	Site*	Alkalinity (mg 1 1)	pH	NH_3-N (mg 1 1)	Kjeldahl N (mg 1 1)	Total P (mg 1 1)	Dissolved Organic C (mg 1 1)
6-17-75	WB-1	25	6.7	0.445	--	0.077	8.0
6-17-75	WB-5	29	6.9	0.435	0.700	0.065	10.8
6-17-75	WB-9	--	--	0.770	1.01	0.196	7.1
6-23-75	HB-1	33.3	7.1	0.370	--	--	24.4
6-23-75	HB-5	--	--	0.490	--	--	37.2
6-23-75	HB-9	30.0	6.8	0.220	0.635	0.057	11.1

Column Water

Date	Site	Alkalinity (mg 1 1)	pH	NH_3-N (mg 1 1)	Kjeldahl N (mg 1 1)	Total P (mg 1 1)	Dissolved Organic C (mg 1 1)
6-17-75	WB-1	26	6.7	--	0.335	0.009	--
6-17-75	WB-5	23	6.7	0.065	0.315	0.009	9.6
6-17-75	WB-9	22	7.0	0.046	0.310	0.006	9.1
6-23-75	HB-1	23.5	7.2	0.066	0.325	0.006	8.3
6-23-75	HB-5	23.0	7.2	0.049	0.405	0.006	--
6-23-75	HB-9	24.5	7.3	0.027	0.325	0.005	8.6

Sediment

Date	Site	% Organics	mg Kjeldahl N / g dry wgt	mg total P / g dry wgt
6-17-75	WB-1	81	29.00	0.466
6-17-75	WB-5	25.5	10.30	0.068
6-17-75	WB-9	26	14.80	0.710
6-23-75	HB-1	3.5	9.80	0.073
6-23-75	HB-5	3.9	2.56	0.205
6-23-75	HB-9	3.8	00.93	0.088

*WB-1,5,9 is Warner Bay 1 meter, 5 meters, 9 meters
HB-1,5,9 is Hearts Bay 1 meter, 5 meters, 9 meters

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