

The Effects of Benthic Organic Matter Quality on Aerobic and Anaerobic Sediment Metabolism in West Falmouth Harbor

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Abstract

Carbon quality, rates of respiration, and rates of dissolved inorganic nitrogen (DIN) release were investigated in aerobic and anaerobic laboratory incubations for three types of sediment from West Falmouth Harbor. Sampling sites were distinguished by the types of dominant primary production found in the overlying water. C:H:N analysis and a sequential extraction of carbon compounds indicated that sediments underlying a bed of macroalgae had the most decomposable Organic matter (OM), followed by Eelgrass sediments and a site characterized by algae detritus and terrestrial inputs. The algal bed sediments had C:N ratios of about 8.19 and 9.01 at 0-3 cm and 6-9 cm depths and the percent water-soluble compounds of organic matter was 2.35 at the 0-3 cm depth compared to values of between 1.0 and 1.5 percent in the other sites and depths. The detrital algal/terrestrial site at 0-3 cm in depth had the most lignin with 71.95 mg/g dry sediment. In both aerobic and anaerobic conditions, the detrital algal/terrestrial site had the highest rates of respiration, followed by the Algal Bed sediments, with Eelgrass sediments respiring the slowest. Initial aerobic respiration in the detrital algal/terrestrial site was $1.96 \text{ mg C g C}^{-1} \text{ hr}^{-1}$, while the algal bed and Eelgrass bed sediments showed rates of 1.04 and $0.65 \text{ mg C g C}^{-1} \text{ hr}^{-1}$, respectively. Anaerobic respiration rates were approximately two orders of magnitude lower than aerobic rates. All samples showed slower rates of respiration at depth in the sediment and all rates decreased over time. During the incubations DIN measurements indicated that net N mineralization was occurring in most of the incubations, however some showed net immobilization.

Introduction

The sediments of estuaries are centers for organic matter decomposition and nutrient recycling. Estuaries are often regions of high production because they are rich in nutrients, partly as a result of allochthonous inputs, and they exhibit diverse habitats where many types of organisms thrive (Hopkinson and Smith, 2004). Approximately twenty-five percent of the production that occurs in estuaries is eventually deposited onto the sediments (Giblin, *per. com.*) and our understanding of the various controls on the decomposition of this organic matter (OM) is crucial to an understanding of the cycling of carbon and other nutrients in these important ecosystems (Rudnick et al. 1991, Cebrian, 2002).

Algae, Eelgrass, and terrestrial OM are common in temperate estuaries and are known to decompose at different rates. In an experiment observing the decay of these three types of OM (Kristensen, 1994), it was found that macroalgae lost 40-44 percent of their carbon over 70 days, whereas seagrasses lost 29-33 percent and tree leaves lost 0-8 percent. The differences observed are largely a result of the differences in carbon quality between the vegetation types. Macroalgae do not have the non-labile vascular tissue that terrestrial plants and seagrasses have. Their structural tissues are made up of less refractory polysaccharides, such as alginates and pectin, with cellulose microfibrils arranged amorphously, and their lignin content is extremely low – no more than 5% in the most extreme cases (Kristensen, 1994). Seagrasses use cellulose as their main structural component and are higher in lignin content than algae, containing up to 10% (Kristensen, 1994). Leaf detritus from terrestrial plants is extremely rich in non-labile organic matter, including lignocellulose and holocellulose, and lignin (Kristensen, 1994).

In a study done by Eyre and Ferguson (2002), it was found that the types of dominant primary producers in the overlying waters of estuarine sediments strongly affect their metabolic rates. The goal of my research is to observe how aerobic and anaerobic sediment decomposition rates in West Falmouth Harbor differ between sediments where varying types of primary producers dominate the overlying water. I would like to find a strong correlation between sediment decomposition rates and the carbon quality of the producers present. Carbon quality is also affected by OM age and I will be comparing decomposition rates at two depths in the sediment to quantify these effects. Observing Nitrogen (N) mineralization trends in areas of differing primary production is another goal of my study because N is a limiting nutrient for these

ecosystems and it allows for better understanding of how sediment microbes are processing OM. Also, it has been found that differences between aerobic and anaerobic metabolic rates are intensified as carbon quality decreases (Rudnick, et al. 1991). I would like to see if my experiment can reproduce these findings.

Dominant primary production can serve as a measure for the extent to which a system has experienced eutrophication. In their study, Eyre and Ferguson (2002) observed lagoons which had experienced different levels of eutrophication, defined by the dominant primary producers of the system. Seagrasses were more abundant in temperate, coastal environments before anthropogenic nutrient loading reached its present intensity. Coastal ecosystems that experience the most intense nutrient loading become anoxic and can become devoid of benthic fauna over time. In these systems, detritus derived from phytoplankton and algae are the dominant sources of organic matter to the sediments. This study and others like it are important because they will help us understand how carbon cycling in coastal ecosystems has changed and will continue to change as a result of eutrophication; this ultimately allows us to better understand the global carbon cycle.

Methods

Site Description. West Falmouth Harbor is an estuary adjoining Buzzards Bay, located on the western coast of Cape Cod, MA. It experiences daily tidal flushing and supports seagrass meadow ecosystems of *Zostera marina* and algal beds consisting of various species. Sediments are generally muddy with the exception of the sandy outer harbor. We sampled from three locations, the first of which was an algal bed (A) in the southern inner harbor. The bed is dominated by *Ulva*, *Gracilaria*, and *Codium*

macroalgae and grows in a fine, muddy sediment. Site 2 is a *Zostera marina* seagrass meadow (E) in Snug Harbor with a muddy fine-grained sediment. Site 3 (DAT) is located approximately 400 meters up the Mashapaquoit river from its entrance to Snug Harbor. It is lower in salinity than the harbor and the only visible OM present is a layer of detrital macroalgae. Conditions of the site were similar to those observed in eutrophied systems and it has been found that a plume of nutrient rich, treated wastewater enters the estuary near this location (Spivey, in press). Terrestrial vegetation surrounding the site consists of *Spartina alterniflora* and hardwood trees. We were careful to take the core from a protected cove so that sediment characteristics would be unaffected by the current. The first 8 cm of sediment is very muddy, giving way to more a coarse, sandy sediment with depth (figure 1).

Sampling and Sample Processing. From each site we collected four sediment cores which were 4 in. in diameter and approximately 8 in. deep. Scuba divers collected the cores at sites 1 and 2. At the lab, we partitioned the cores into segments, keeping the 0-3 cm and 6-9 cm depths. We homogenized and dried the depth segments from one core from each site for carbon quality tests and C:H:N analysis. We sealed the segments from the remaining three replicate cores from each site and transferred them to a sealed glove bag which was purged with N₂ gas to create an anoxic environment. In the bag, we filled two 75 mL jars with homogenized sediment from each depth segment and sealed them for anaerobic respiration and nutrient analyses. We removed the remaining samples from the bag and transferred 30 mL of homogenized sediment from each sample to incubation cores. The cores are 5 cm in diameter and approximately 12 cm deep, and can be fitted with a sealed chamber with ports for the Li-Cor 6200. We added 120 mL of filtered

seawater to each core and mixed the water and sediment thoroughly to create slurries. The slurries were kept mixing on a shaker table and we covered them with parafilm to keep them from sloshing out of the cores during mixing. We made small holes in the centers of the parafilm coverings to keep conditions oxic.

Aerobic Respiration Methods. We took measurements of aerobic respiration at four time points throughout the course of two weeks using a Li-Cor 6200. At each time point we took the slurries off of the shaker table just before the measurement was made to keep the sediment suspended. The Li-Cor was set up to log 15 measurements of CO₂ in ppm over a 240 second time interval. Using slopes of plots of Li-Cor CO₂ measurements vs. time, we manipulated the Ideal Gas Law to calculate aerobic respiration in mols of CO₂ per second. After calculating carbon content in the sediments from C:H:N analysis, we scaled the measurements to units of mg C g C⁻¹ hr⁻¹ (Shaver, 2005).

Anaerobic Respiration. We measured anaerobic respiration using a sealed jar experiment. For all replicates we prepared initial and final sealed jars. All of the initial jars were opened at an initial time point and the final jars were opened at three successive time points. We opened one replicate per time point for the final jars. We used the initial time point of approximately 2 days to ensure that the jars had gone anoxic. The three successive time points were spaced over the course of the next 10 days. At each jar opening, we transferred the sediment to 50 mL centrifuge tubes and spun them for 10 minutes at 10,000 rpm. We mixed 4.5 mL of the supernatant with 9 mL 0.1 M NaCl and measured conductivities for 10 uniform additions of HCl which was delivered with a hack titrator. Using values for the initial HCl addition needed to reach the 195 – 200 mV

range and data for the changes in mV between subsequent additions, we calculated the alkalinity of the supernatant using a simple computer program (Giblin).

Separation of Organic Matter into Carbon Fractions. We sequentially extracted carbon fractions of varying lability from three aliquots of dried sediment from each site and depth using protocol from Ricca (1992) and Robertson et al. (1999). Three replicates were used for each depth segment. From the four part procedure, we chose to exclude the extraction of non-polar organic matter. Because sediments are poor in carbon content compared with soils, we used 15.0 g dry sediment for the water soluble extraction, and 4.00 g dry sediment for the acid digestion.

Nitrogen Methods. At each aerobic and anaerobic respiration measurement time point, we took water samples from the slurries and jars for NH_4^+ and NO_3^- tests. To extract the water from the aerobic slurries, we removed them from the shaker table for 1 to 1.5 hours to allowed the sediment to settle, and pipetted out 5 mL for each N analysis. We replaced the extracted water with filtered sea water and filled the core to its original volume with DI water to correct for evaporation. For anaerobic N tests we used the same supernatant that was obtained for Alkalinity measurements. We also ran KCL extractions on 3.0 g subsamples from each site by shaking the samples vigorously with 15 mL 2N KCL, centrifuging the subsamples, and collecting supernatant for N tests. NO_3^- concentrations were measured using the Lachat Quikcham 8000 and NH_4^+ concentrations were quantified using methods from Strickland and Parsons (1972).

Results

Aerobic Respiration. Initial aerobic respiration was highest in the 0-3 cm DAT slurry with a rate of 1.967 ($\text{mg C g C}^{-1} \text{ hr}^{-1}$). The initial respiration rate for this site in the 6-9

cm slurry was approximately 1/3 of the 0-3 cm rate. The 0-3 cm A slurry exhibited an initial rate of 1.049 which was nearly 4 times as high as the 6-9 cm rate of 0.297. Site E showed initial rates of 0.654 for the 0-3 cm slurry and 0.272 for the 6-9 cm slurry. In the first 150 hours of incubation, respiration rates decreased less than they did for any of the other time intervals, with the exception of the DAT 6-9 cm slurry, which decreases by nearly half its initial value. After approximately 150 hours all of the 0-3 cm slurries exhibited larger decreases in respiration rate over time. The 6-9 cm slurries for A and E did not show strong decreases until after 200 hours. Final respiration rates, taken after 280 hours of incubation, for DAT 0-3 and 6-9 cm slurries were 0.664 and 0.154 cm respectively. Rates for A 0-3 and 6-9 cm slurries were 0.267 and 0.134, and rates for E 0-3 and 6-9 cm slurries were 0.239 and 0.076. In general, rates began to converge over time (figure 2).

Anaerobic Respiration. Averaged anaerobic respiration rates, expressed as $\text{mg C g C}^{-1} \text{ hr}^{-1}$, were between one and two orders of magnitude lower than averaged aerobic rates (table 1). Anaerobic respiration data did not show strong trends over time like aerobic data, with the exception of data from A 6-9 cm. In this site, respiration decreased linearly over a 180 hour incubation with an R-squared value of 0.999. The final rate was 40 % of the initial rate. Similar to aerobic respiration, DAT 0-3 cm showed the highest rate at 0.058, A 0-3 cm showed the next highest rate at 0.045, and E 0-3 cm had the slowest rate of the 0-3 cm segments at 0.033. Trends in anaerobic 6-9 cm respiration rates were opposite aerobic trends. E showed the highest rate at 0.017, the average rate in A was 0.008 and DAT had the lowest rate at 0.001. Differences between 0-3 cm rates and 6-9

cm rates were greater in anaerobic treatments than they were in aerobic treatments (table 1).

Sequential Extraction of Carbon Fractions. In site A 0-3 cm there was 1.71 mg of water soluble organic matter (WS) per g dry sediment. The value for the 6-9 cm treatment was about half of the 0-3 cm treatment. Site E showed 1.44 mg/g dry sediment in the 0-3 cm sediments and 0.85 in the 6-9 cm sediment. DAT had values of 1.16 and 0.66 for depths 0-3 cm and 6-9 cm respectively. Acid soluble (AS) fractions of Organic matter were similar between treatment types but decreased with depth. Lignin was significantly lower in A 0-3 cm than in other treatments at 48.7 mg/g dry sediment. E 0-3 cm was high in Lignin with a value of 68.4 mg/g dry sediment and DAT 0-3 cm was the highest of all sites and depths with 71.9 mg/g dry sediment. Lignin values decrease with depth in all treatments and of the 6-9 cm depths, E has the most lignin at 56.5 mg/g dry sediment. Total organic matter in mg/g dry sediment decreased with depth in all treatments. A had significantly low values for OM compared to the other treatments of the 0-3 cm depth. The largest discrepancy in organic matter between depths occurred in DAT (figure 2). Carbon fractions expressed as percentages of total OM showed much less variation. A 0-3 cm differed the most from other treatments. Its percentage of WS organic matter was about 2 times higher than the other treatments and % Lignin values were significantly lower as well. % OM of Dry g sediment was variable between treatments and depths. All sites in the 6-9 cm depth had lower percentages than their corresponding 0-3 cm depths (table 2). In the 0-3 cm depths A had the lowest percent of OM (table 2).

Correlation of C fraction Data with Respiration. Initial Aerobic respiration measurements (in mg C respired $\text{g C}^{-1} \text{hr}^{-1}$) were plotted against % WS organic matter (OM). In general sites with higher percentages of WS OM respired at a faster rate. The plot was fitted with a trend line which had a slope of 0.4496 and an R-squared value of 0.5326 (figure 3). Average anaerobic respiration for the incubation (in mg C respired $\text{g C}^{-1} \text{hr}^{-1}$) was plotted in the same way and a similar trend was noticed. The R-squared value was 0.8321 and the slope was 0.031 (figure 4). % Lignin was also plotted, and for both aerobic and anaerobic respiration, rates decreased with increases in % Lignin. The R-squared values were 0.6226 and 0.8125 and the slopes were -10.048 and -0.0039 respectively (figures 5, 6). Each of the plots excluded data points from the 0-3 cm depth of the DAT site because they were outliers.

Nitrogen fluxes. In the aerobic cores at 0-3 cm depths, total mineral N in $\mu\text{mols/g C}$ increased with time in E and A and decreased with time in DAT (figure 7). At the 6-9 cm depth E and DAT showed net decreases in N and A showed a net increase. In general, total N changes were about one order of magnitude higher in the 0-3 cm depth (figure 8).

In the anaerobic cores at the 0-3 cm depth, All sites showed net increases in N during the incubations, with DAT showing a net increase of about 2 times those of the other sites (figure 9). In the 6-9 cm depth DAT and E showed fluxes in N over during the incubation but the net changes were minimal. Site A showed a net increase in N of about 2/3 that of its increase in the 0-3 cm depth (table 3, figure 10).

Some of the C:N ratios of the mineralization fluxes were close to redfield. For the Anaerobic 6-9 cm E incubation, the ratio was 37:1 (table 5).

Discussion

OM Quality. According to data from C:H:N analysis and the sequential extraction of carbon compounds, the macroalgae bed contained the highest quality OM. There was less lignin and more WS compounds, and C:N ratios at both depths were lower compared to other sites. Eelgrass bed sediments were intermediate in OM quality and The detrital Algal/terrestrial sediments were lowest in quality based on the same tests (tables 4& 3). DAT OM quality data could be misleading because we believe that the site has both high and low quality sources of substrates. The detrital algal source is very labile whereas terrestrial inputs, carried downstream by the mashapaquoit river or blown into the water from *Spartina alterniflora* vegetation and hardwood trees, make up a non-labile OM source. Terrestrial inputs have the potential to greatly skew carbon OM quality tests because they have C:N ratios and percent lignin values of more than 3 times those of Eelgrass (Kristensen, 1994). We have assumed that the detrital algal OM in the DAT site is higher in quality compared to OM from the other two sites and that it is responsible for high respiration rates.

Aerobic and Anaerobic Respiration. Aerobic respiration data provided evidence that carbon quality, as a function of age and source, exerts strong controls on respiration rates. Initial respiration measurements at depth were between 25 and 50 percent of their corresponding 0-3 cm rates. Initial respiration data showed that between treatments, E and A were approximately 30 and 55 percent of DAT respiration at the 0-3 cm depth and were both about 38 percent of DAT at depth. These data indicate that the differences in OM quality of these primary producers affect sediment respiration rates nearly as much as the differences in carbon quality resulting from the age of the material being

decomposed. Differences in respiration rates between treatments are consistent with findings from Kristensen (1994) that macroalgae decompose faster than seagrasses. The decreases in respiration rates over time for all sites and depths were significant but, did not vary in magnitude excessively except for the 6-9 cm incubation in DAT.

The decreases in aerobic respiration over time were such that the rates seemed to converge. If the incubation period had been longer and a more sensitive instrument had been used to measure respiration we might have seen the rates become very similar. Our observation is consistent with similar findings in a terrestrial decomposition experiment done by Berg (2000). As OM decomposes, it becomes enriched in lignin and N making it very recalcitrant. Therefore, samples that are variable in OM quality at the beginning of an incubation become more similar in quality as lignin becomes more concentrated, causing decomposition rates to converge (Berg, 2000).

Anaerobic respiration rates provided evidence that OM age has a greater effect on decomposition than source. In A, E, and DAT, respiration rates for the 6-9 cm depth were 18, 53, and 1.5 percent of their corresponding rates at 0-3 cm. Between treatments at the 0-3 cm depth, rates varied by about 35 percent at most. The larger differences in decomposition rates between depths found in anaerobic conditions are consistent with findings in the literature that OM quality has a greater effect on anaerobic decomposition than it does on aerobic decomposition. Rudnick (1991) found that fresh phytoplankton detritus decayed 1.1 times faster in aerobic conditions compared with anaerobic conditions and that aged detritus decayed 1.4 times as fast.

Rudnick (1991) found that during a 19 day incubation in aerobic conditions, fresh and aged phytoplankton detritus decayed at rates 1.106 and 0.394 percent per day,

respectively. The 14 day aerobic incubation yielded comparable results. Averaged respiration rates for the incubation were 3.45 and 0.92 percent per day for the 0-3 cm (fresh) and 6-9 cm (aged) DAT sediment, 1.34 and 0.57 percent per day for the fresh and aged A sediment, and 1.13 and 0.54 percent per day for the fresh and aged E sediment. Differences in fresh and aged decomposition were similar between the two experiments, however base respiration rates in our experiment were higher which we think is a result of differences in experimental setup since the aerobic slurries were incubated in warm and highly oxic conditions compared to those in Rudnick's flow-through system.

Correlation of Nitrogen fluxes with Respiration. In the 0-3 cm depth for the aerobic cores site A and E showed net mineralization of N. As the incubation period proceeded, respiration rates decreased in these sites, however changes in total N mineralized remained rather constant. Site DAT showed net immobilization of N which could be due to Nitrogen poor organic matter as a result of allochthonous inputs. C:N ratios were highest in DAT treatments (table 4). In the 6-9 cm depths E and DAT show net immobilization of N while A shows net mineralization.

In anaerobic conditions at the 0-3 cm depth, all sites showed net mineralization of N with DAT showing approximately double the net increase in mineral DIN of the other sites. The much higher increase points to the greater efficiency with which detrital algal/terrestrial sediment was decomposing. In aerobic conditions DAT 6-9 cm showed clear immobilization of N. The opposing trends between anoxic and oxic conditions for this site could be due to the slower anaerobic respiration rate. Since the site is N poor and oxic respiration is very efficient, increased uptake of mineral N is necessary to sustain the high metabolism of the microbial population. The anaerobic treatment shows

respiration rates of one to two orders of magnitude lower (table 1). Therefore, even though the sediment is N poor relative to other treatments, there is enough N available for the inefficient respiration. For the 6-9 cm depths, A was the only site with clear net mineralization, while E and DAT showed little net change in $\mu\text{mols N/g C}$. The only site at which net mineralization was observed at both depths and in both oxic and anoxic conditions was A.

Where net N mineralization was observed, the magnitudes of DIN changes did correspond to respiration rates, with the most efficient respiration measurements corresponding to the highest releases of DIN. The one exception to this trend was in the 0-3 cm aerobic incubation in which A showed lower DIN release than the slower respiring E. C:N ratios of Respired carbon to mineralized nitrogen correlated in some cases with literature. Ratios for phytoplankton detritus, green macroalgae, and seagrass undergoing decomposition should be 6.6, 10, and 27, respectively (Eyre & Ferguson, 2002). Some of the ratios that we measured were comparable to expected Redfield fluxes (table 5). E showed a C:N flux in the 6-9 cm segment of 37:1 under anaerobic conditions which is comparable to the expected flux for seagrasses. The C:N ratio may be higher than expected because the OM deeper in the sediment is aged and has become more enriched in refractory compounds.

Conclusions

The study of sediment metabolic rates in areas where different primary producers dominate the overlying water is important because it allows us to better understand carbon cycling in marine systems. Primary producers such as Eelgrass and terrestrial leaves have high concentrations of recalcitrant materials that decay over very long

periods of time. Refractory compounds are created during decay and become buried in sediments. Labile primary production, such as phytoplankton and the detritus resulting from algal blooms, decompose very quickly (Cebrian, 2002).

Anthropogenic nutrient loading has resulted in more frequent occurrences of harmful macroalgae and phytoplankton blooms and more eutrophied systems. The environments that nutrient loading creates are detrimental to Eelgrass and have served to decrease its abundance greatly in recent years. Nutrient Loading in coastal ecosystems can result in decreased carbon export to marine sediments because it favors the production of more decomposable primary producers. Understanding the severity of the discrepancies in decomposition rates of different primary producers allows us to better understand the effects eutrophication on the global carbon cycle.

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Figures

1. Map of West Falmouth Harbor. Snug Harbor, Inner South Harbor, and sampling sites are labeled.
2. Aerobic Respiration in $\text{mg C g C}^{-1} \text{ hr}^{-1}$ vs. Incubation time in hours. Solid lines represent 0-3 cm depths and dashed lines represent 6-9 cm depths. Data points are averages of three replicates.
3. Carbon Fractions expressed in $\text{mg OM/g dry sediment}$. The sums of the fractions represent total $\text{mg OM/g dry sediment}$.
4. Aerobic Respiration ($\text{mg C g C}^{-1} \text{ hr}^{-1}$) plotted against %WS OM of total OM. A positive relationship is shown.

5. Anaerobic Respiration ($\text{mg C g C}^{-1} \text{ hr}^{-1}$) plotted against %WS OM of total OM. A positive relationship is shown.
6. Aerobic Respiration ($\text{mg C g C}^{-1} \text{ hr}^{-1}$) plotted against % Lignin of total OM. A negative relationship is shown.
7. Anaerobic Respiration ($\text{mg C g C}^{-1} \text{ hr}^{-1}$) plotted against %Lignin of total OM. A negative relationship is shown.
8. DIN ($\mu\text{mols N/g C}$) at the 0-3 cm depth in the aerobic cores at four time points during incubation.
9. DIN ($\mu\text{mols N/g C}$) at the 6-9 cm depth in the aerobic cores at four time points during incubation.
10. DIN ($\mu\text{mols N/g C}$) at the 0-3 cm depth in anaerobic sediments at four time points during incubation.
11. DIN ($\mu\text{mols N/g C}$) at the 6-9 cm depth in anaerobic sediments at four time points during incubation.

		Aerobic	Anaerobic
0-3 cm	A	1.048 ± 0.346	0.044 ± 0.0037
	E	0.654 ± 0.060	0.032 ± 0.0058
	DAT	1.966 ± 0.320	0.057 ± 0.0144
6-9 cm	A	0.297 ± 0.013	0.008 ± 0.0022
	E	0.272 ± 0.041	0.017 ± 0.0072
	DAT	0.748 ± 0.132	0.001 ± 0.0004

Table 1. Rates of Respiration ($\text{mg C g C}^{-1} \text{ hr}^{-1}$) with standard error. Anaerobic values are averaged from all time points. Aerobic values are from initial respiration data.

		% WS	% AS	% Lignin	% OM of dry sediment
0-3 cm	A	2.35	30.75	66.90	7.28
	E	1.55	25.12	73.33	9.32
	DAT	1.23	22.12	76.65	9.39
6-9 cm	A	1.25	22.61	76.14	6.82
	E	1.15	22.38	76.47	7.39
	DAT	1.03	22.24	76.72	6.39

Table 2. C fraction percentages of total OM and OM percentage of dry sediment.

		Aerobic conditions	Anaerobic Conditions
	Time (hrs)	276	257
0-3 cm	A	264.51	131.69
	E	473.21	101.63
	DAT	-358.48	242.03
6-9 cm	A	52.95	80.85
	E	-24.36	10.19
	DAT	-22.84	-22.00

Table 3. Change in DIN ($\mu\text{mols N/g C}$) over the entire incubation periods.

		% C	% N	C:N ratio
0-3 cm	A	3.68	0.45	8.19
	E	4.98	0.56	8.52
	DAT	3.20	0.34	9.57
6-9 cm	A	2.91	0.32	9.01
	E	3.69	0.38	9.81
	DAT	3.42	0.31	11.01

Table 4. % C, %N and C:N ratios for all sites and depths averaged from two replicates.

		Aerobic	Anaerobic
0-3 cm	A	3.8	5.6
	E	1.6	4.0
	DAT	--	1.9
6-9 cm	A	--	1.9
	E	--	37.0
	DAT	--	--

Table 5. C:N ratios of mineralized carbon and nitrogen during the course of the incubations. Value are absent where net immobilization was observed.



Figure 1.

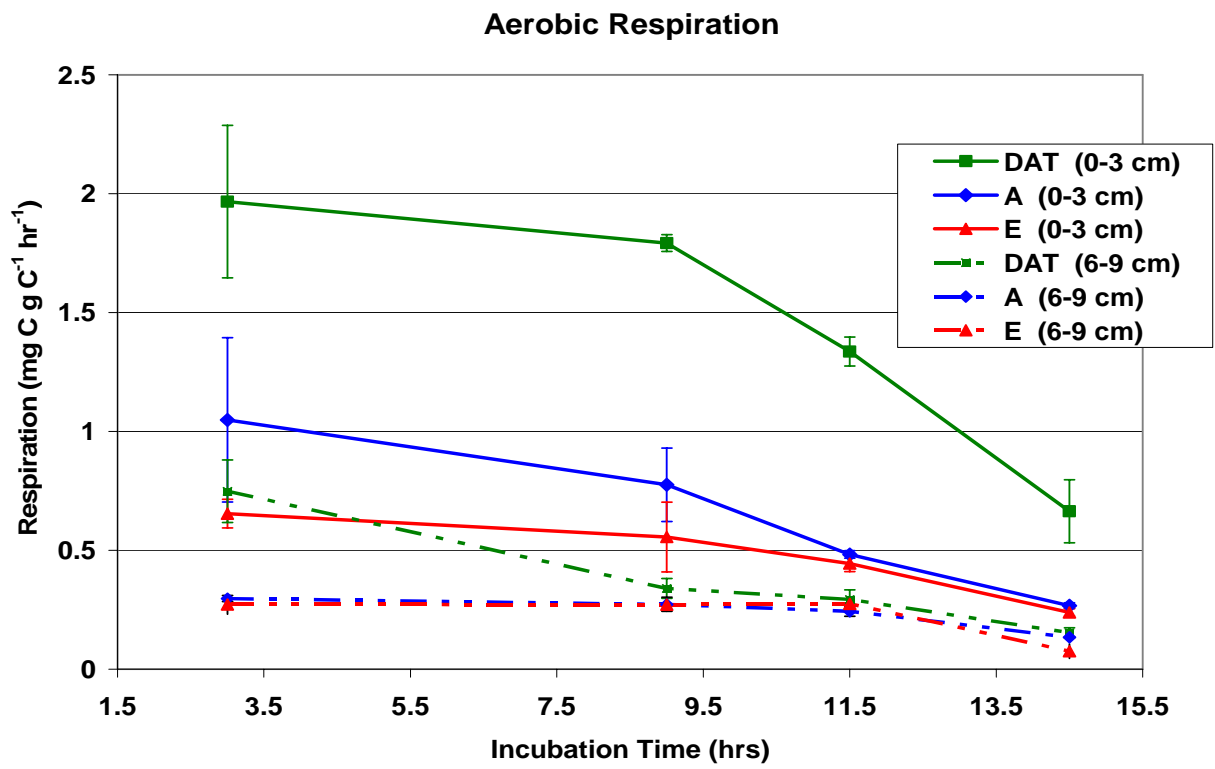


Figure 2.

Carbon Fractions

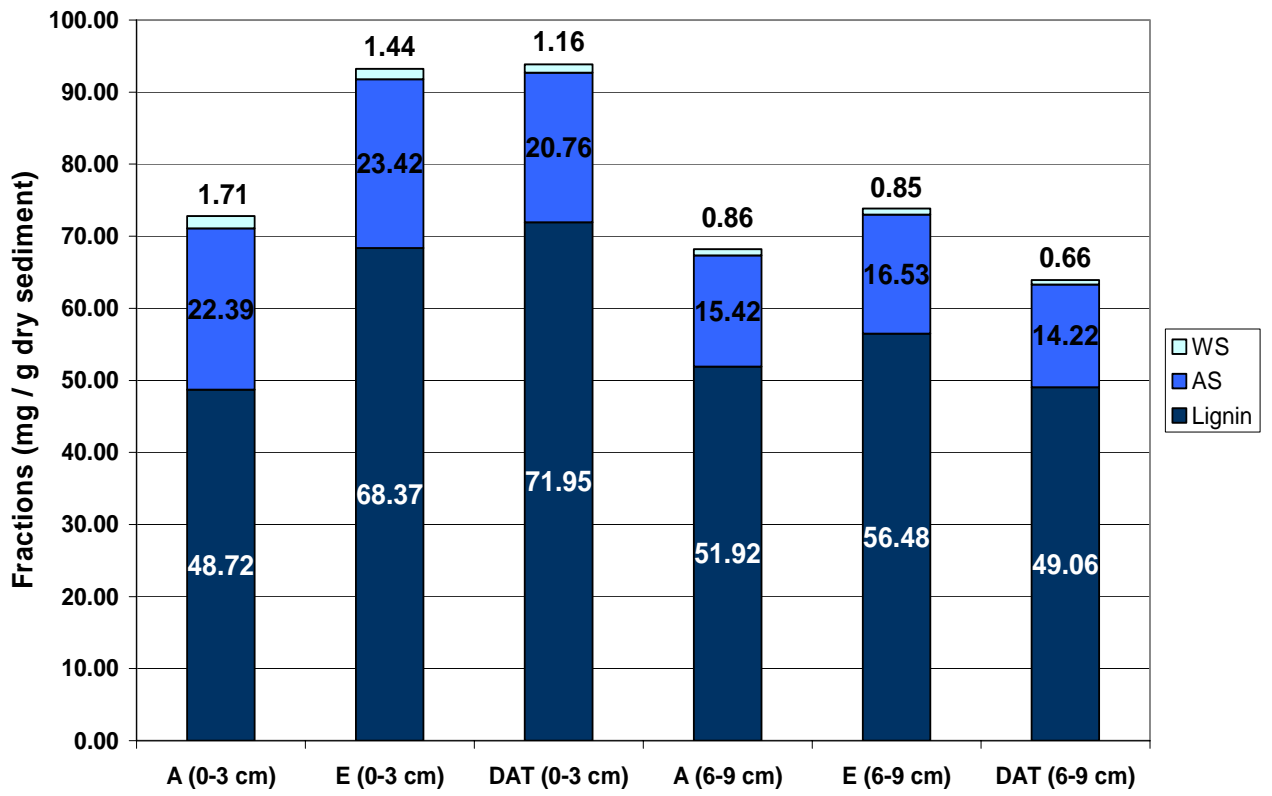


Figure 3.

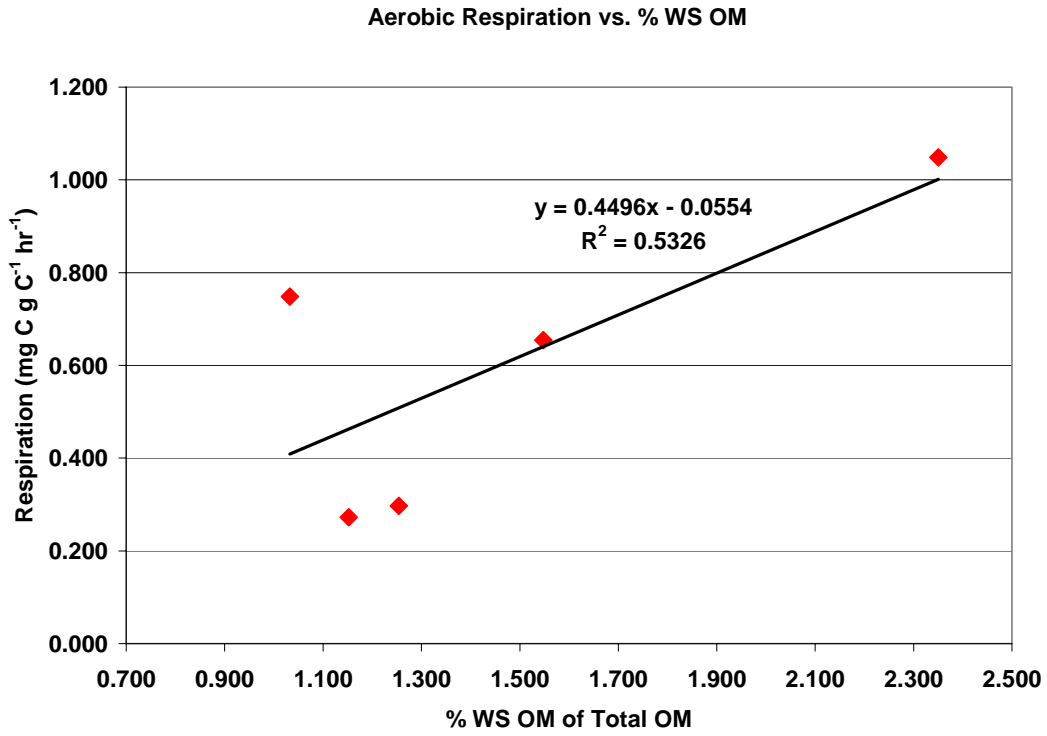


Figure 4.

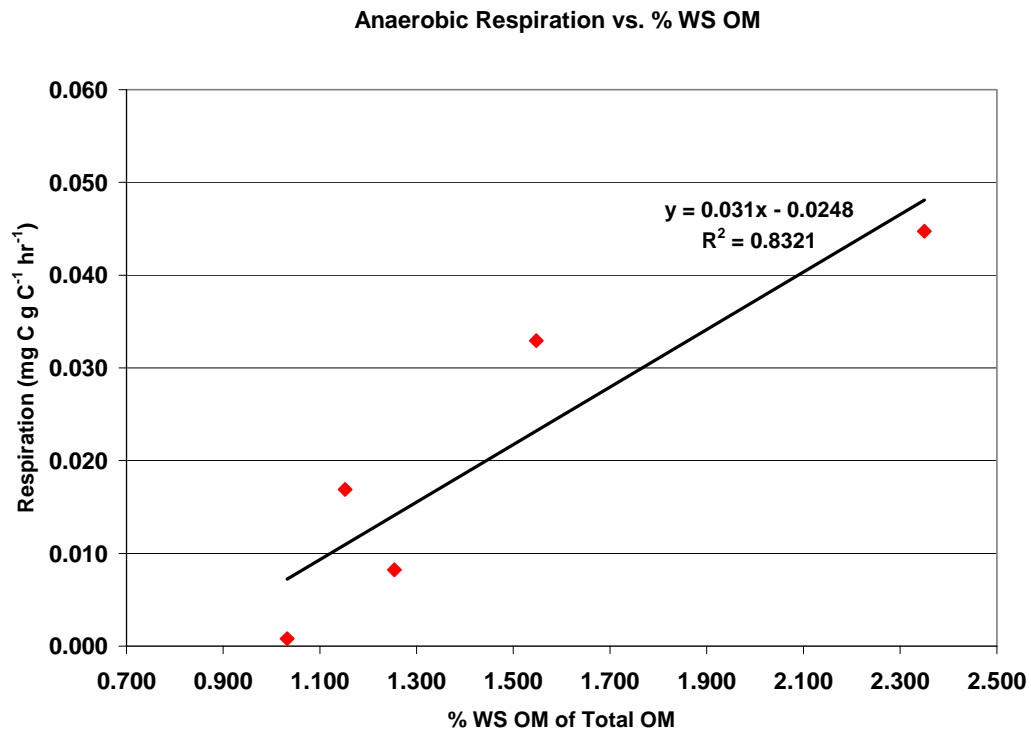


Figure 5.

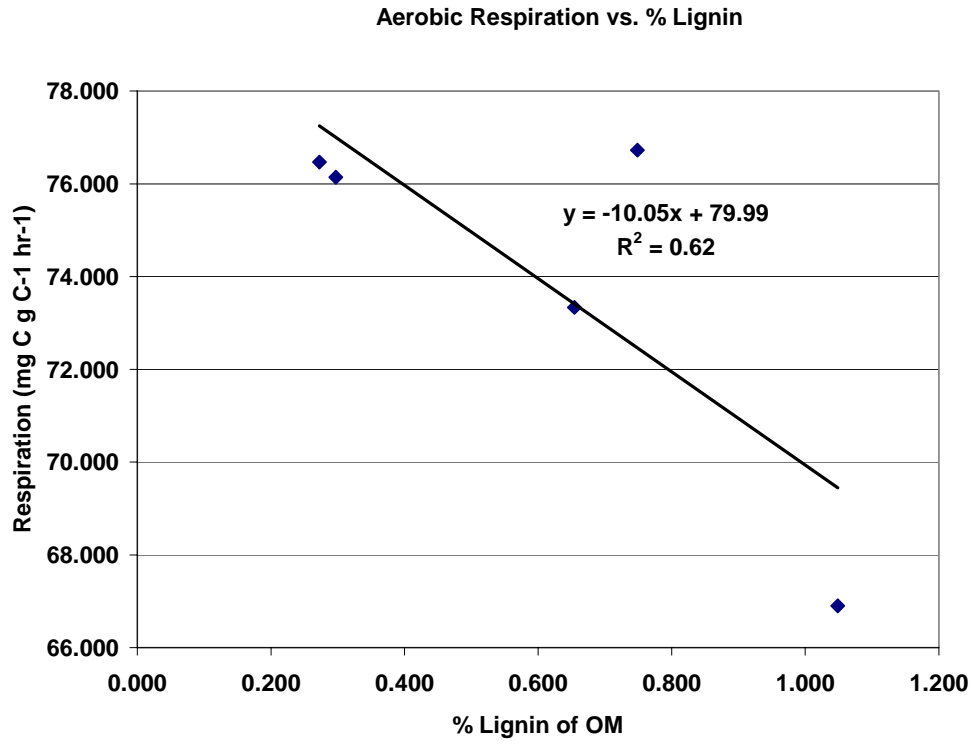


Figure 6.

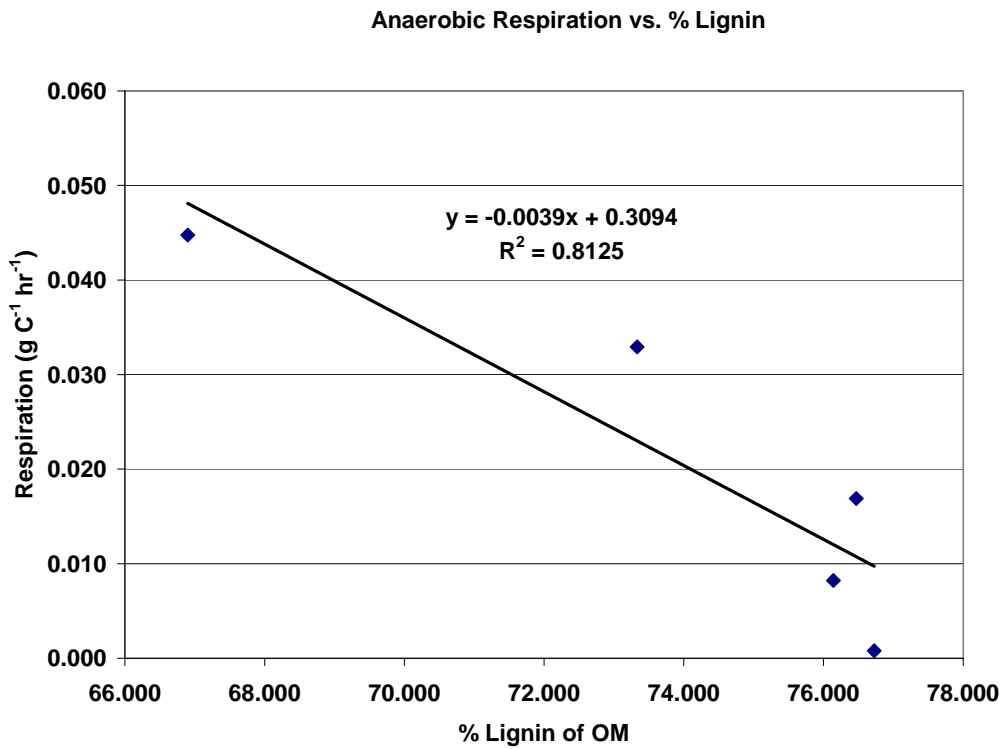


Figure 7.

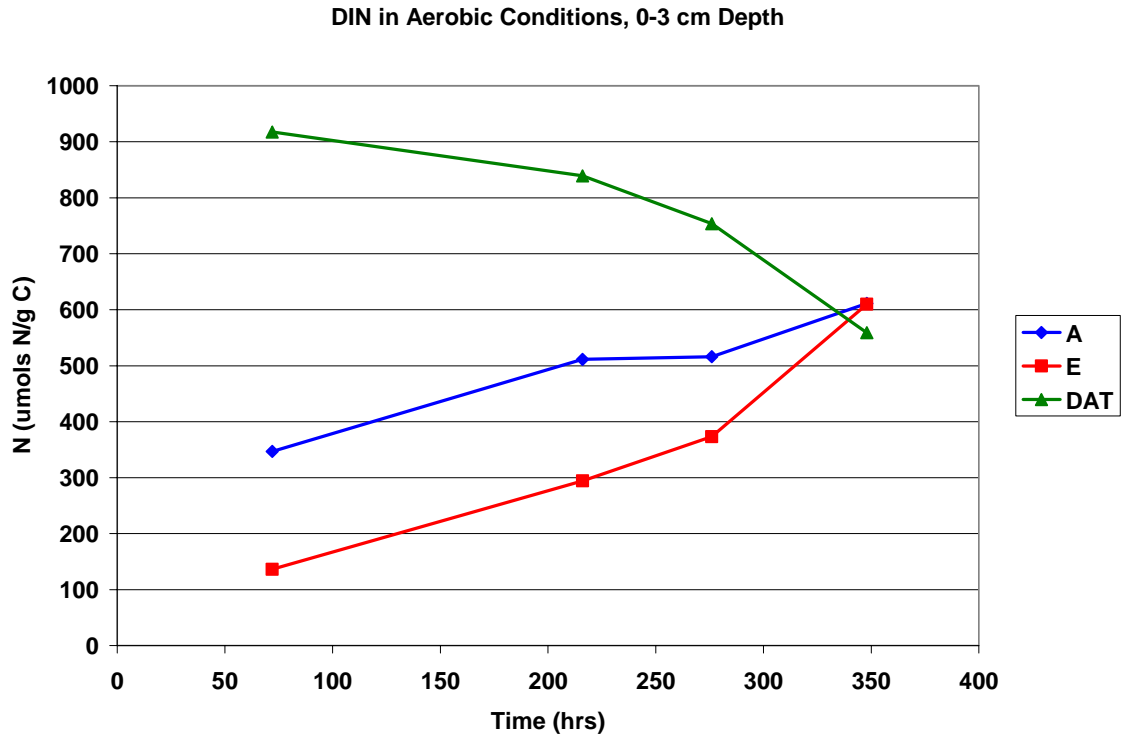


Figure 8.

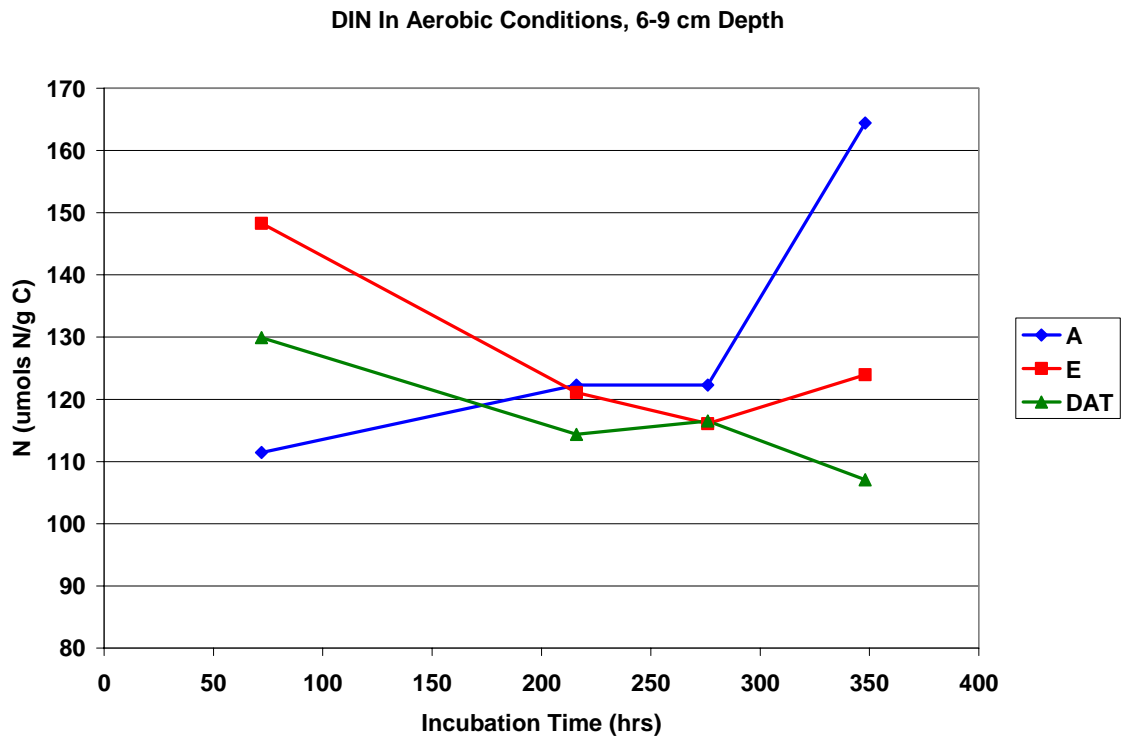


Figure 9.

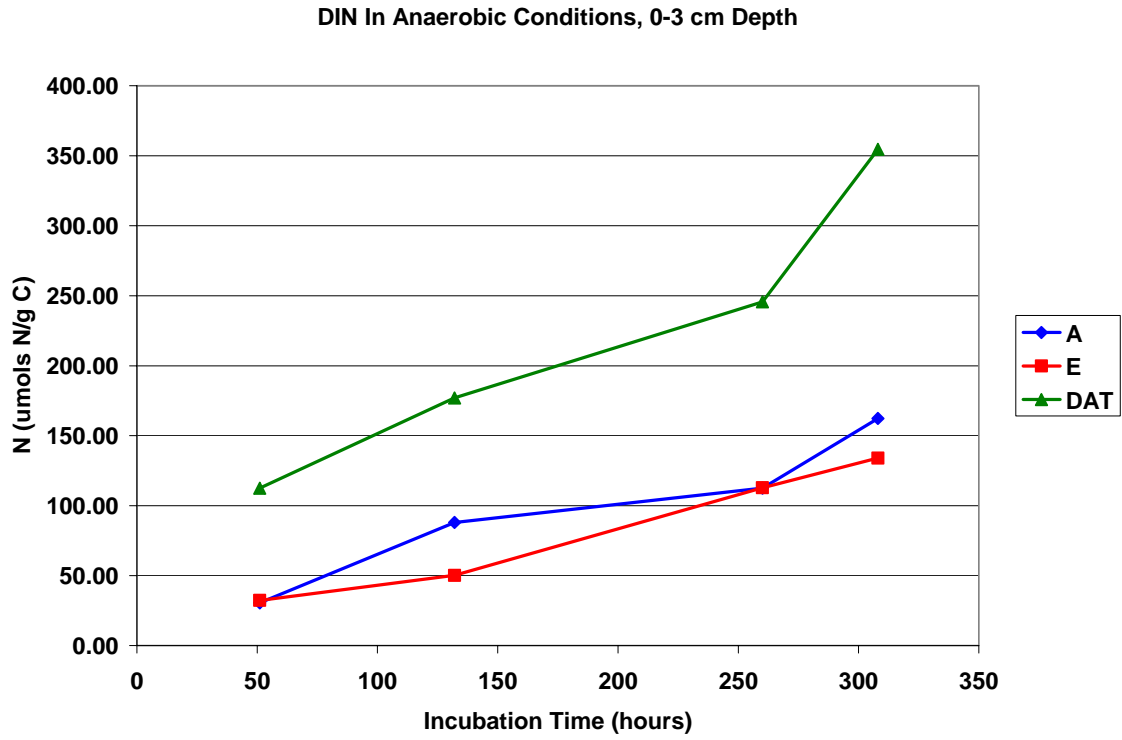


Figure 10.

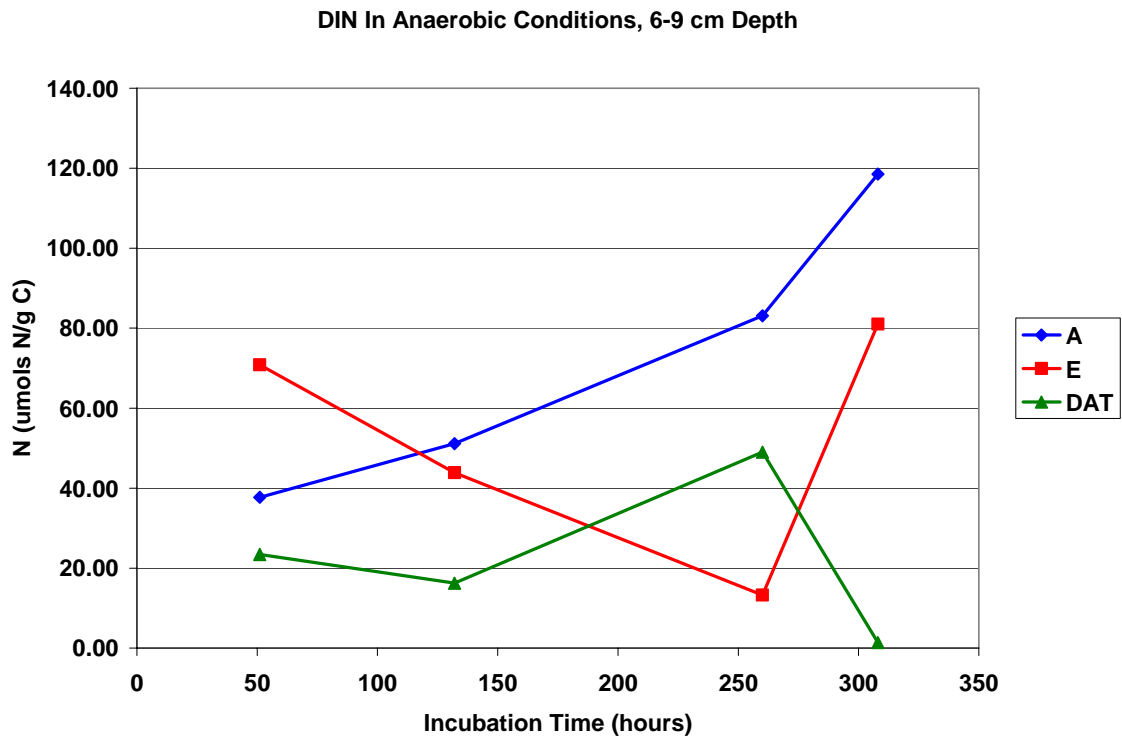


Figure 11.