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Particulate Organic Matter in a Riffle of Tenderfoot Creek

Abstract

The purpose of this study was to determine whether a riffle on Tenderfoot Creek in the University of Notre Dame Environmental Research Center was a net user or net producer of carbon in the form of particulate organic matter. After determining the area and discharge of the riffle, I measured autotrophic productivity as well as masses of both imported and exported fine and coarse particulate organic matter. The results showed that the riffle exports much more organic matter than it takes in with both production and importation combined. I believe that high flow conditions and possibly sampling site selection skewed the results to show extremely high exports.

Introduction

The changing global climate is currently a huge concern among the scientific and academic communities as well as a large portion of the general population. People want to know what is causing it, how extreme resulting problems may be, and what can be done about them. What are we going to do if the polar ice caps melt? If boreal forests become deserts? If we have too much UV radiation coming through the ozone? These are all phenomena that people are concerned about, but before we can predict the gravity of the effects caused by global climate change, we have to know a lot more about how our earth works now.

One of the first steps in learning about our world's function is to figure out how and where energy is created, distributed, and used by the complex processes in the environment and to quantify it in the form of a global budget. Energy is often measured as carbon, the raw material from which nearly every organism derives a substantial

portion of its fuel. Such budgets have been drawn up, but increasing the amount of information by which scientists estimate their numbers can only lead to more and more accurate budgets.

Forests are a huge carbon sink; deforestation by logging and other, more destructive methods are causing great fluxes in our global carbon budget. Boreal wetlands are another storage area. Trying to determine the part that streams and rivers play in the global carbon budget is a bit of a rough science because very little is known about streams outside of North America or about large rivers anywhere in the world (Hauer and Lamberti, 1996). Unfortunately, this study was also confined to a portion of a small, North American stream, but every little bit helps in the pursuit of global awareness.

Primary production by autotrophs serves as the basis of every food web on this planet and, thus, is an important factor in the creation of energy budgets. In streams, autotrophic production by algae, cyanobacteria, bryophytes, and vascular macrophytes contribute a substantial fraction of total fixed carbon. Algae especially serves as a critical food resource for lotic herbivores. The food value of algae is much greater than that of detritus and can support grazer biomasses 10 to 20 times that of its own mass (Hauer and Lamberti, 1996). Even sloughed algal biomass is important to filter feeders and as a source of detritus. As a matter of fact, sloughed algae and other autotrophs make up a substantial portion of coarse and fine particulate organic matter (POM) transported through streams. In situations where there is little allocthonous input by lateral transport or leaf litter, autochthonous organic matter from autotrophs may be the dominant coarse and fine POM transported by a stream.

Because changes in algal biomass may indicate changes in stream productivity or environmental conditions, it is definitely important to quantify the transported algal biomass and the algal productivity of a stream in order to estimate its carbon budget. That is precisely what this study attempted to do. The experimental site was a riffle on Tenderfoot Creek, located in northern Wisconsin, U.S.A. on the property of the University of Notre Dame's Environmental Research Center (UNDERC). I measured POM imports and exports as well as the primary productivity of algal communities in order to determine where the stream's energy is coming from, where it is going, and in what form. This also shows whether the riffle is a net producer or net consumer of energy in the form of carbon.

Materials & Methods

Riffle Dimensions

The first step in this mensurative study was to determine the general dimensions of the riffle under study, including length, width, depth, velocity and discharge. I began by establishing two transects, one at the upstream end and one at the downstream end, across the creek with nylon rope and demarcating them with flags at one-meter intervals. These transects served as reference points at which to take measurements and samples.

To find the length of the riffle, I sunk posts into the streambed at about center width wherever there was a change of direction in the stream's path. I then measured the straight-line distance between the posts from the upstream transect to the downstream transect to get a good estimate of the overall length. I determined average width of the

riffle by taking the width of the creek at 13 locations roughly 10 meters apart, including width at the transects.

To determine average velocity at each transect, I divided the upstream transect into four cells 2.5 meters wide and the downstream transect into six cells 3 meters wide. I then measured the depth at the center of each cell and used a velocity meter to measure the water movement at the center of each cell at roughly 60% depth when possible. Multiplying width times depth times water velocity gave me the discharge of each cell. I took the average of the upstream cells and the average of the downstream cells to find the average discharge at the upstream and downstream transect, respectively. I used these two numbers to calculate the average discharge of the whole riffle as well.

Riffle Productivity

In order to determine productivity of the riffle, I needed to measure gross primary production. I went out to the stream before the sun had risen high enough to provide the stream with direct sunlight (before the autotrophs could begin the day's production) and I collected random rocks from the areas near the upstream and downstream transects. I placed them in four impermeable zipper freezer bags, two replicates from upstream and two replicates from downstream. I then filled a bucket with stream water, measured the dissolved oxygen concentration in the water with a dissolved O_2 meter, and used this water to fill the bags. I first did a dark incubation to determine respiration by placing the zipper bags in black plastic bags. I placed them in the shallows near the edge of the stream in order to minimize temperature changes and let them sit for five hours.

After five hours, I measured the dissolved oxygen concentration of the water in each zipper bag. This change represented community respiration in each bag. I then

measured the dissolved oxygen in some fresh stream water and used it to replace the old water in the zipper bags. They sat for another five hours in the shallows of the stream, but this time were exposed to ambient sunlight rather than being covered by opaque plastic. I again measured the dissolved oxygen in each zipper bag after the incubation and this change represented net primary production. The amount of oxygen produced during net primary production plus the amount of oxygen lost due to respiration represents gross primary production.

After the final O_2 measurements, I brought the rocks back to the lab, dried them, and determined their surface area. I measured surface area by wrapping each rock in a single layer of aluminum foil, trimmed to remove any overlap, and then compared the mass of the foil required to cover the rocks from each replicate to the mass of $100cm^2$ of the same aluminum foil. Some simple division yielded the surface area of each replicate. I estimated that roughly 50% of the total surface is exposed to the sun and, thus, photosynthetically active, so I halved each surface area in order to find the photosynthetically productive area.

Finally, I determined the total primary production per area by multiplying the dissolved oxygen concentration in each zipper bag by the average volume of water left in the zipper bags after the rocks were removed and then dividing that number by the photosynthetically productive area of the replicate. Next I converted oxygen production to carbon production using equation 25.5 from Hauer and Lamberti (1996):

$gramsC = gramsO_2 \times (1/PQ) \times (12/32)$

where: PQ = photosynthetic quotient (assumed to be 1.2 for this study)
12 = atomic weight of carbon
32 = molecular weight of O_2

After determining the primary production of the replicates, I found an average production for each sampling and multiplied it by the area of the riffle to determine total primary production for the riffle per 24 hours. I then used these numbers to find the average daily primary production for the whole riffle for the period from mid-June to mid-July.

Particulate Organic Matter

In order to monitor inputs and outputs of particulate organic matter (POM) from the riffle under study, I set aside three sampling days during the summer: June 16, July 1, and July 12. Each day, I took four sets of samples over 24 hours, one at 0000, one at 0600, one at 1200, and one at 1800 hours. Each set of samples consisted of three 1-liter water samples taken at each transect to be filtered for fine particulate organic matter (FPOM) and three coarse particulate organic matter (CPOM) samples taken by holding a 1mm mesh net in the water column for 15 minutes per sample. I removed the CPOM from the net by shaking it into a bucket and washed the CPOM from the bucket into a sample jar using a squirt bottle full of stream water. Each set of samples took nearly two hours to collect; the above times are times when sampling began. At the upstream transect, I took samples at the 3, 5, and 7 meter marks; at the downstream transect, I took them at the 6, 10, and 13 meter marks. I chose these sampling sites because they had no obstruction directly upstream and they were sufficiently deep to put the sampling net all they way into the water.

Back in the lab, I filtered the POM samples onto Whatman GF/F glass microfiber filters (catalogue number 1825 047) pre-weighed to 0.1mg. I poured the FPOM samples through 1mm mesh screen into the filtration apparatus in order to remove any coarse particles. I filtered off water from the CPOM samples with 1mm mesh screen in order to

remove any fine particulates that I may have added to the samples when using the squirt bottle full of stream water.

I dried the filters and samples to constant weight on aluminum weigh boats in the muffle furnace at 105°C for at least 24 hours. I then cooled the filters and samples in desiccators and massed them to the nearest 0.1mg. This mass minus the original filter mass represents the dry mass of the sample. Next, I ashed the filters and samples on aluminum weigh boats in the muffle furnace at 500°C for at least an hour. Then I allowed the furnace to cool down to 105°C, cooled the filters and samples in desiccators, and massed them to the nearest 0.1mg. This mass minus the original filter mass represents ash mass of the samples. Dry mass minus ashed mass represents the ash-free dry mass of the organic matter collected in each sample.

Organic Matter Budget

The culmination of this mensurative study was to use all of my acquired information to determine whether the riffle under study is a net user or net producer of organic matter assuming that the change in storage over a one month period is negligible.

I used the particulate organic matter data to calculate the average masses of CPOM and FPOM transported at each transect at each time on each sampling day. I then took the average of each set of four numbers to find the mean CPOM and FPOM masses transported per sample on each sampling day. I used these average masses per sample volume and the transect discharge to calculate the projected mass of FPOM and CPOM to pass each transect in the water column on each sampling day.

I then used the total masses from all three days to calculate the average FPOM and average CPOM to pass the upstream transect in 24 hours. I added these together to

find total daily imports. Daily imports plus daily carbon production is total carbon input into the stream riffle. I also calculated the average FPOM and average CPOM to pass the downstream transect in 24 hours. Together, these represented total daily exports as well as total daily carbon output. If the input was larger than the output, the riffle would be a net carbon user; if the output was larger than the input, then the riffle would be a net carbon producer.

Results

Riffle Dimensions

The total length of the riffle under study on Tenderfoot Creek was 136.26 meters. The average width turned out to be 14.85m. The average depth of the stream at the center mark of the width measurements was about 25cm. This depth measurement was usually, but not always, taken in the thalweg.

At the upstream transect, the depth of the cells ranged from 26 to 34.5cm with an average of 29.5cm. The velocity of the cells ranged from .57m/s near the banks to 1.79m/s near the thalweg with an average of 1.08m/s. The total upstream discharge was $3.29m^3/s$. At the downstream transect, The depth of the cells ranged from 12 to 22cm with an average of 18cm. The velocity of the cells ranged from 1.06m/s to 1.50m/s with no distinct thalweg. The total downstream discharge was $4.46m^3/s$. Taking the average of the two discharges resulted in a mean riffle discharge of $3.88m^3/s$. Please see Table 1.

Riffle Productivity

Primary productivity samples taken on June 14 and July 10, 2001, produced results consistent with sensible expectations and with one another. Every replicate

produced a negative change in oxygen concentration during the dark incubation and a positive change in oxygen concentration during the light incubation. This made sense because it meant there was respiration without photosynthesis in the dark incubation and both in the light incubation. Temperature changes were kept to a minimum, less than 2°C in most replicates and less than 3.2°C in all replicates.

Changes in oxygen concentration were generally higher in the replicates from the area of the downstream transect. This indicates that, for the most part, more production and respiration were taking place in these replicates. Average overall production for the upstream replicates was 11.79g carbon/m^2, while the downstream replicates produced an overall average of 20.66g carbon/ m^2. However, using average production for both transects on each sampling day produced fairly similar results; 31.1kg of carbon produced on June 14 and 34.5kg of carbon produced on July 10. On average, the riffle on Tenderfoot Creek produces about 32.8kg of carbon per 24-hour day. Please see Table 2.

Particulate Organic Matter

All three POM sampling days were successful. Each FPOM sample had a volume of .001m^3, or one liter. I calculated the volumes of the CPOM samples according to the average discharge of the stream at the transect from which the sample was taken. Each sample from the upstream transect had a volume of 27.05m^3, while each sample from the downstream transect had volume of 32.81m^3. For summaries of average masses of organic matter according to date and time collected, please see Figures 1-4.

A three-way analysis of variance (ANOVA) performed on the FPOM data with sampling date, time of day, transect location, and interactions of these three as sources of variation concluded that sampling date and transect location were significant with p-

values of less than 0.001. Neither time of day nor any interaction terms proved to be significant sources of variation. An identical ANOVA on the CPOM data had similar results. Sampling date was significant with a p-value of less than 0.001 and transect location was significant with a p-value of 0.016. Again, neither time of day nor any interaction terms proved to be significant sources of variation. Please see Table 3 for further statistical information.

Organic Matter Budget

The mass of the average daily import of particulate organic matter into the riffle ended up being 274.6kg, of which nearly 274.4kg was FPOM. The mass of the average daily export turned out to be 642.2kg, of which about 641.6kg was FPOM. This resulted in a net export of 334.8kg of carbon every day. The riffle is a net carbon producer. Please see Table 4 for more detailed numerical information.

Discussion

Riffle Dimensions

The problem with my method of measuring the dimensions of the riffle was that I had to substitute several straight line measurements for curved meanders in the path of the creek. It was also sometimes difficult to determine the edges of the creek or even reach the edges if they were distinct because of dense brush, abundant rocks, and fallen timber along the banks. The length and width of the riffle could probably be more easily determined using an aerial photograph with a scale, but again, the banks would be terribly obscured by trees and brush. Being right in the creek has advantages for bank

recognition. With GPS and GIS systems becoming very accurate, measurement of the length of meandering streams will surely get better in the majority of experimental sites.

There was an obvious discrepancy between the average discharge at the upstream transect and the downstream transect. One would expect them to be much closer unless there was significant input into the stream due to drainage of a smaller creek into the riffle or major inputs of groundwater in the form of a spring. I found neither tributary nor spring within the riffle, but I have other hypotheses as to why the average discharge measurements were so different. First, at the upstream transect, the flow of the stream was undisturbed and clear of debris, but several meters upstream there lay a large fallen tree that may have created an artificial slowing of the water flow along the east bank of the riffle. Along the west bank, a concentration of rocks and brush seemed to delineate the edge of the stream, but I think some water may have actually been flowing beneath the debris that I could not include in the discharge analysis. Both of these factors may have artificially lowered my discharge measurements at the upstream transect. At the downstream transect, the water flow was wide, shallow, and turbulent due to a rough, cobbled stream bed. The turbulent, shallow flow may have made for inaccurate measurements with the velocity meter; plus, I was able to have more cells over which the error could increase. These factors may have artificially inflated my discharge measurements at the downstream transect. Despite their shortcomings, these locations were the most regular and navigable sites for the placement of transects. Placing them at other locations would have created even more error because of irregular flow and difficulty in using instruments.

Riffle Productivity

An oversight on my part forced me to make a rough estimate in my calculations for carbon production of the riffle. I failed to measure the volume of water left in the zipper bags after I had taken the rocks out. I had tried to be fairly consistent in how much rock I placed in each replicate during the real experiment, so I re-enacted the experimental conditions and placed a similar volume of rock in another zipper bag. Based on this re-enactment, I estimated that each replicate contained around one liter of water in which the oxygen concentration changes took place.

The data for the second sampling day, June 26, had to be thrown out because it was so unreasonable that it could not have been an accurate representation of what truly happens in the riffle production system. I got negative oxygen production values for all of the light incubations except one. I even had one replicate in which the light incubation produced a greater negative oxygen change than the dark incubation. This made for nonsensical values of negative carbon production. There were several other confounding factors that contributed to the problems of this sampling day. One was that the dissolved O_2 meter I began using that morning was taken and I had to finish using another O_2 meter that could have been calibrated differently than the first. Another problem was that Mother Nature was not cooperating. The day was very overcast and rainy and there was an inordinately large number of invertebrates on the rocks to contribute to the respiration measurements. Perhaps there were so many invertebrates because the lack of sun did not force them to seek shelter in the sediments of the creek bottom. The other two sampling days went much more smoothly and produced much more consistent numbers.

There was an interesting pattern in that the downstream replicates almost always had higher production and respiration values than the upstream replicates. This can probably be explained by the fact that the downstream reach of the riffle was much wider and shallower than the upstream reach. Because it was wider, the autotrophs probably received a longer period of direct sunlight. Because it was shallower, there was also a thinner layer of water with suspended matter to filter and disperse the sunlight. Both of these factors would allow the downstream autotrophs to be healthier and more prolific than those upstream. Thus, I suggest that the rocks in the downstream replicates supported more autotrophs in their biofilm than the rocks of the upstream replicates and that the downstream autotrophs were probably also more efficient in using available sunlight because they were healthier.

Particulate Organic Matter

This proved to be the most trying part of the experiment as far as fieldwork goes. It took several failed attempts with scavenged materials from the lab and storage shed before I fashioned an adequate CPOM sampling net out of an old kick net and some 1mm plastic window screen. The sampling days were difficult; I would spend around nine hours standing in the stream and another four fours in the lab each day with only intermittent sleep throughout the 24-hour period.

Still, all of the data collected was sensible and usable. At one point I was worried because many of the final ash-free dry masses (AFDMs) were coming out with a negative value. The only thing that could have been causing this problem was that the filters were losing mass in the drying and/or ashing processes. Using three sets of ten of the same GF/F filters I used for filtering the particulate organic matter, I did three rounds of tests

for filter loss using conditions identical to the actual experiment. I pre-massed the filters to the nearest 0.1mg, dried them at 105^0C, and massed them again. There was no significant change at this step. However, when I fired the filters at 500^0C, the filters lost an average .0018g. Adding this mass to my AFDMs reconciled the problematic negative values.

The location of the transect at which the POM data were collected was a statistically significant source of variation. I suggest that this has to do with the varied productivity of different parts of the riffle. As I discussed earlier, the downstream reach of the riffle probably had more numerous and healthier autotrophs because the stream was wider and shallower and thus received more direct sunlight. With more algae overall, it makes sense that there would be more algae sloughing off the rocks and sediments of the streambed and the downstream transect would see greater algal transport in the water column.

Sampling date was also a significant source of variation for the FPOM and CPOM data. I suggest that this variation was mainly due to the noticeable fluctuation of water levels over the course of the season. Above average rainfall in late spring and early summer contributed to high water levels in the streams and lakes of the area, and Tenderfoot Creek was no exception. Towards the end of June, I could tell that some of the boulders in the stream were protruding from the water more than they had when I first arrived at UNDERC. In late July, the water level was obviously lower. The water along the banks had receded, revealing cobbles that were not visible earlier in the summer. Several fish spawning beds became exposed to air. Several times it was even difficult to keep the entire net submerged at a few of my sampling sites.

Changes in water level certainly had an affect on the POM transport. Above average influxes from the watershed most certainly would increase algal sloughing in the stream and perhaps bring in extra particulate matter due to erosion of stream banks and some runoff. I doubt erosion would make that much difference, however, because the surrounding land is so thick with trees and vegetation. There is a conspicuous decrease in mass of organic matter sampled from Day 1 (June 16) to Day 2 (July 1) on all four POM figures. The mass of CPOM sampled continues to decrease through Day 3 (July 12), but the mass of FPOM takes an upswing on the third sampling day when the water level was at its lowest. I cannot adequately explain this, but I do remember seeing large quantities of yellow pollen floating on the surface of the lakes on the property around that same time. Since Tenderfoot Creek is an outflow of Tenderfoot Lake, perhaps this pollen was collecting on the lake and them being transported into the creek. This could increase the FPOM masses sampled from the creek. Another possibility is that extra sediment was deposited on the riffle during the period of high flow and was beginning to be re-eroded as the water level fell.

This change in water level over the course of the experiment made me realize that it would probably be a benefit to similar studies in the future if they measured the stream discharge on every day that particulate organic matter sampling was done. This would lead to more accurate figures of the volume of water that passed through the sampling net and, in turn, better estimates of total imports and exports.

Organic Matter Budget

There is a monstrous discrepancy between net daily input and net daily output. As a matter of fact, my calculations predict that the riffle exports 27.3kg more carbon

every day than its combined imports and production accumulate. It seems this would be impossible to maintain under normal conditions, so I suggest the conditions under which my experiment was performed were deviant from the norm.

As I have previously noted, the water level in the riffle was very high during the first day of POM collection. Judging by my calculations, this greatly increased the amount of POM suspended for transport in the water column. On the first sampling day, the mass of fine organic matter that hypothetically passed the upstream transect was more than triple that of the next sampling day and more than double that of the third sampling day. FPOM exports fluctuated according to the same pattern with the first day having the highest masses and the second day the lowest. The CPOM imports nearly tripled the masses on the second day and surpassed those of the third day by a factor of five. The CPOM exports on the first day also were nearly triple that of the second day's sample and, similar to the imports, surpassed the masses of the third day by nearly a factor of five.

Now, although the raised water levels may have played some part in the extremity of the discrepancies, they do not explain how the divergence could still be so large on regular-flow days. Since most of the stream in the area of the downstream transect was so shallow, I am led to believe that the places deep enough to accommodate my net may have actually represented above-average flow for that part of the stream. Perhaps large cobbles or other obstructions diverted water to these areas, or maybe they were paths of least resistance because they had less large cobble on the bed. If they were areas of higher flow, they would also carry with them more particulate organic matter and

contribute to the skewed results. Considering I used these sites consistently throughout the course of the experiment, the error may have compounded itself with the calculations.

Conclusions

Unfortunately, this study did not serve its original intended purpose of determining conclusively whether the riffle on Tenderfoot Creek in Notre Dame's Environmental Research Center is normally a net user or net producer of carbon in the form of particulate organic matter. Despite the skewed information, I would hypothesize that the riffle is a net producer under normal conditions given that the export numbers were consistently larger on each testing day. Although this cannot be proven by my analysis, I do not believe that the methods were errant enough to miss the general trend of POM production and transport in the creek system. A future study for the same purpose should be performed over a longer time period, perhaps a year, so extreme POM measurements can balance each other out and result in a more representative average. Also, discharge variations must certainly be taken into account with each POM collection because using an "average" discharge figure may prove quite inaccurate with any given season.

Although this study partially failed in its original purpose, it can still be used as an example of the drastic changes that can occur in a lower-order lotic ecosystem even over a short duration. In the time span of a month, masses of transported organic matter could potentially change by several hundred percent multiple times and water level can shift noticeably in a matter of days. Such variation is easily displayed in lower-order aquatic ecosystems because even a small change in the watershed can be compounded in magnitude several times by the time it begins to affect the outpouring stream. As a

matter of fact, I seriously doubt that the changes which confounded my experimentation would be considered large by most stream ecologists, perhaps not even above normal. Streams are generally dynamic ecosystems which really only have "normal" conditions when scientists take averages of their variation. This study could have been much more drastically affected by severe climactic conditions such as flooding caused by severe rainfall or extremely low water levels caused by drought.

It is difficult to account for all the variation in stream ecosystems, but such studies to determine energy production and use must not be abandoned. They must be designed more carefully and cover a broader scope of time and space in order to become more accurate and get a true sense of "normal" conditions. As they are expanded to higher-order streams and rivers all over the world, hopefully these studies will help lead to a greater understanding of energy flow in our worldwide ecosystem. This knowledge is necessary for humans to determine where energy is coming from, where it is going, and what role we play in this transfer. We must not disturb the rhythms of the planet that sustains us so much as to lead to our own destruction.

Literature cited

Hauer, F. Richard and Lamberti, Gary A., eds. Methods in Stream Ecology. San Diego: Academic Press, 1996.

Table 1. Cell measurements used to calculate discharge at transects.

Upstream Transect

Cell (2.5m)	Depth (cm)	Velocity (m/s)	Discharge (m^3/s)
1	26	0.60	0.39
2	30	1.79	1.34
3	34.5	1.36	1.17
4	27.5	0.57	0.39
		Average	**Total**
		1.08	**3.29**

Downstream Transect

Cell (3.1m)	Depth (cm)	Velocity (m/s)	Discharge (m^3/s)
1	19	1.18	0.69
2	21.5	1.34	0.89
3	22	1.46	1.00
4	20.5	1.50	0.95
5	13	1.06	0.43
6	12	1.33	0.49
		Average	**Total**
		1.31	**4.46**
		Mean Riffle Discharge (m^3/s):	**3.88**

Table 2. Dark and light incubations used to quantify riffle carbon production

14-Jun-01 **Dark Incubation** **Light Incubation**

	O_2 change	*Temp change*	*O_2 change*	*Temp change*	*GPP (mg/L)*	*Productive Area (cm^2)*	*gC produced/m^2*
UP 1	-1.04	1.1	1.1	1.7	2.14	454.42	6.69
UP 2	-1.29	0.6	2.3	1.7	3.59	426.80	11.22
DWN 1	-1.73	0.4	4.63	1.6	6.36	564.59	19.88
DWN 2	-2.42	0.7	5.19	1.7	7.61	740.36	23.78
						Average:	**15.39**
						Riffle C Production for day (g):	**31134.26**

10-Jul-01 **Dark Incubation** **Light Incubation**

	O_2 change	*Temp change*	*O_2 change*	*Temp change*	*GPP (mg/L)*	*Productive Area (cm^2)*	*gC produced/m^2*
UP 1	-2.73	2.5	2.04	2.2	4.77	513.46	14.91
UP 2	-2.5	2	2.09	1.7	4.59	521.57	14.34
DWN 1	-0.64	2.5	3.79	0.8	4.43	540.96	13.84
DWN 2	-3.39	3.1	4.66	1.4	8.05	657.15	25.16
						Average:	**17.06**
						Riffle C Production for day (g):	**34516.36**

Upstrm Average gC produced/m^2: 11.79

Dwnstrm Average gC produced/m^2: 20.66

Riffle Avg. Daily C Production (g): 32825

Table 3. Three-way analyses of variance on FPOM and CPOM data.

FPOM: sampling date*time of day*transect location (upstream or downstream)
Balanced Design
Dependent Variable: AFDM Value
Normality Test: Failed (P = <0.001)
Equal Variance Test: Passed (P = 0.080)

Source of Variation	DF	SS	MS	F	P
Date	2	0.0000138	0.00000691	23.977	<0.001
Time	3	8.82E-08	2.94E-08	0.102	0.958
Transect	1	0.00000903	0.00000903	31.352	<0.001
Date x Time	6	0.000000869	0.000000145	0.503	0.803
Date x Transect	2	0.000000663	0.000000332	1.151	0.325
Time x Transect	3	0.000001	0.000000334	1.159	0.335
Date x Time x Transect	6	0.000000946	0.000000158	0.547	0.77
Residual	48	0.0000138	0.000000288		
Total	71	0.0000402	0.000000567		

CPOM: sampling date*time of day*transect location (upstream or downstream)
Balanced Design
Dependent Variable: AFDM Value
Normality Test: Failed (P = <0.001)
Equal Variance Test: Passed (P = 0.127)

Source of Variation	DF	SS	MS	F	P
Date	2	0.0372	0.0186	13.764	<0.001
Time	3	0.00425	0.00142	1.049	0.38
Transect	1	0.00839	0.00839	6.216	0.016
Date x Time	6	0.00263	0.000438	0.324	0.921
Date x Transect	2	0.00359	0.0018	1.33	0.274
Time x Transect	3	0.00533	0.00178	1.317	0.28
Date x Time x Transect	6	0.00825	0.00138	1.019	0.424
Residual	48	0.0648	0.00135		
Total	71	0.134	0.00189		

Table 4. Average daily masses and total daily transport of POM

Daily Average (g)	UF	UC	DF	DC
Day 1	0.0016333	0.044691667	0.002125	0.086216667
Day 2	0.0004917	0.016250000	0.001150	0.028941667
Day 3	0.0007667	0.008016667	0.001725	0.018566667

Daily Trasport

Import (g/day):	FPOM	CPOM
Sample Volume (m^3)	0.001	27.0459
Mass Day 1	464926.20	470.3642573
Mass Day 2	139952.28	171.0256017
Mass Day 3	218230.67	84.3726302
Average	274369.72	241.9208297
Total Imports:	**274611.64 grams/day**	

Export (g/day):	FPOM	CPOM
Sample Volume (m^3)	0.001	32.805675
Mass Day 1	818166.23	1011.870333
Mass Day 2	442772.31	339.669985
Mass Day 3	664158.47	217.905191
Average	641699.00	523.148503
Total Exports:	**642222.15 grams/day**	

Imports + Production =	**307436.95 grams/day**
Net Carbon Exported =	**334785.20 grams/day**

Figures 1-4. These graphs give summaries of average masses of organic matter collected according to sampling date and time of day.

Figure 1.

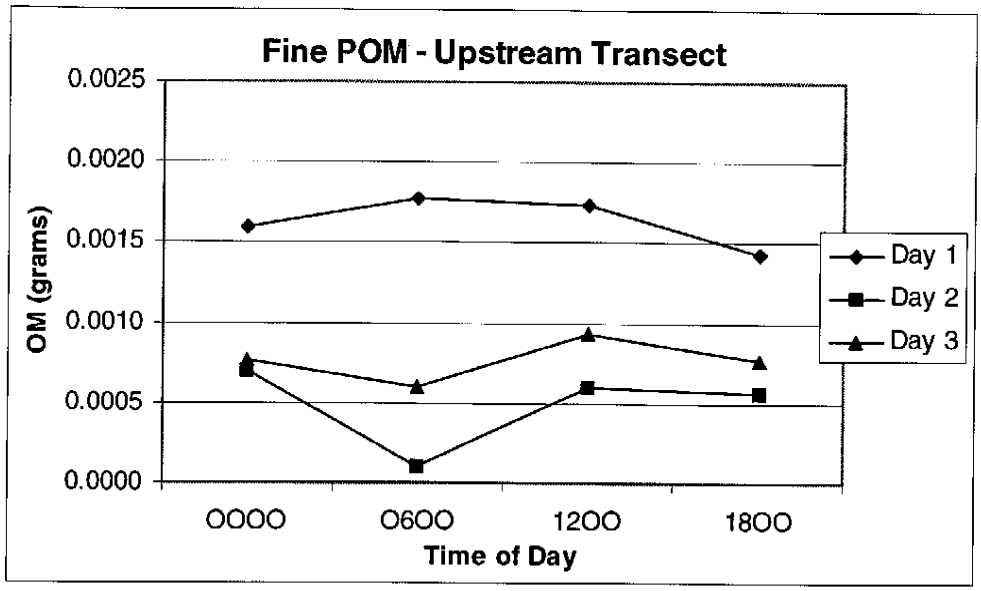

Figure 2.

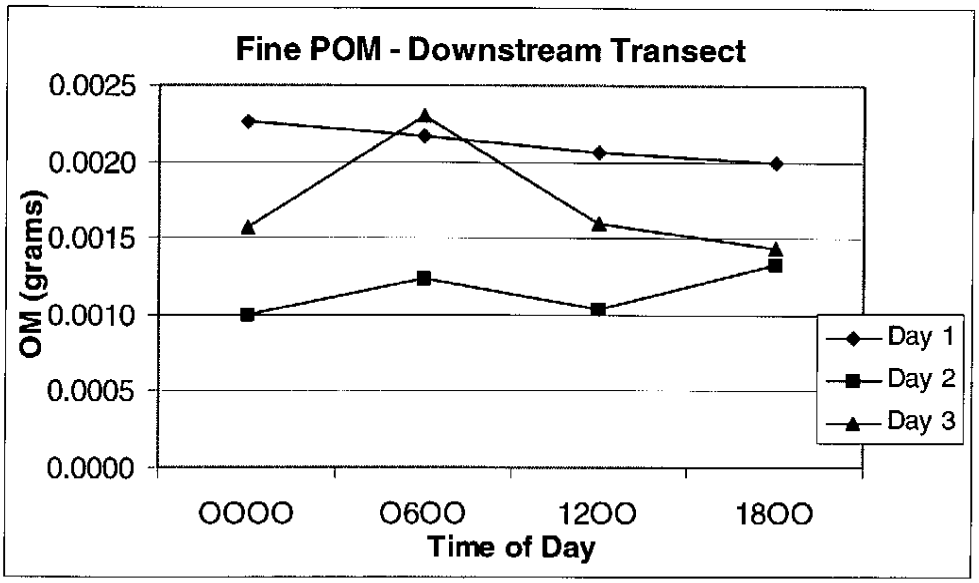

Figure 3.

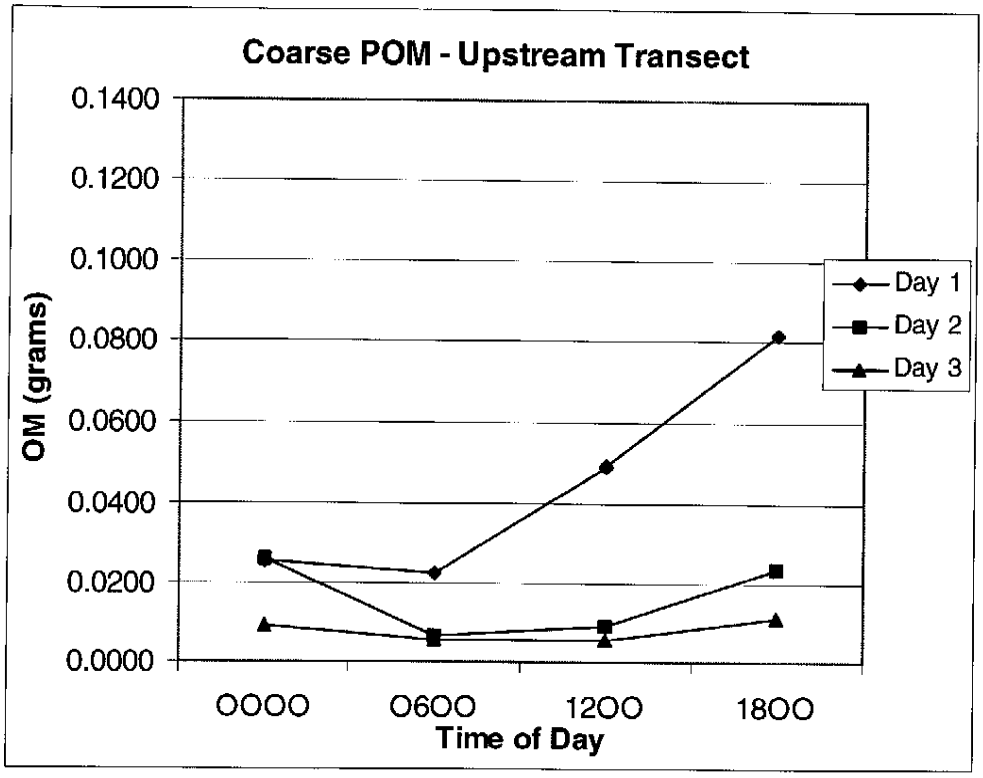

Figure 4.