Species Identity of Shredder Macroinvertebrates on Organic Matter Processing

BIOS 569: Practicum in Field Biology

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Abstract

The detrimental effects of human activity in freshwater ecosystems have caused losses to biodiversity in these environments. If species identity plays an important role in organic matter processing by shredding macroinvertebrates, then changes in shredder assemblages in headwater streams may be altering the rate of production of FPOM (fine particulate organic matter). This experiment consisted of a mesocosm study system utilizing isopods, amphipods, and caenid mayflies to study how the rate of organic matter processing, and the quantity and size of the fine particulate matter produced varied with species identity over time. I also examined how species richness affected organic matter processing and fine particulate matter production. I did not find a significant difference between species identities in organic matter processing or fine particulate matter production. Species richness had no effect on organic matter processing. I found that some species have a more significant role on ecosystem functioning than others. Hyalella amphipods were found to be a dominant species whose presence or absence is more important than other shredding macroinvertebrates.

Introduction

The scientific community is concerned about the loss of global biodiversity and the possible effects of this loss in ecosystems (Jonsson and Malmqvist 2000, Loreau 2004). Decreasing biodiversity is generally attributed to the detrimental effects of human activity (Dangles and Malmqvist 2004, Tilman et al. 1997 and Iwata et al 2003). Humans have exploited the resources of many ecosystems without adequate knowledge of the possible ecological consequences of their actions on the maintenance of these same resources (Naiman and Turner 2000). Freshwater ecosystems have suffered greatly from these actions (Iwata et al. 2003); therefore, many freshwater ecosystem functions and services may be affected. Included among these are flood control, groundwater renewal, sediment trapping, nutrient recycling, biological productivity and preservation of water quality and quantity (Meyer et al. 2003).

Streams have many different functional groups (Wallace and Webster 1996). Organisms are divided by their morphological characteristics and feeding behavior (Wallace and Webster 1996, Jonsson and Malmqvist 2003). These groups are shredders, collectors, filterers, grazers and predators (Wallace and Webster 1996). It has been found that these functional guilds show a high connection between each other (Jonsson and Malmqvist 2005). Shredders convert coarse particulate organic matter (CPOM), mostly in the form of leaf litter, to fine particulate organic matter (FPOM) by the mechanical action of feeding and excretion (Webster anf Benfield 1986). These feces are filtered or collected by other organisms living alongside them and further downstream in order to obtain nutrients (Jonsson and Malmqvist 2005, Vannote et al. 1980, Wallace and Webster 1996). Since shredders are intermediate consumers, any impact they suffer in their ecosystem function could cascade into adjacent trophic levels (Wallace and Webster 1996, Jonsson and Malmqvist 2005).

The river continuum concept describes changes in the ecological patterns that occur on a longitudinal gradient of a stream (Vannote et al. 1980). It states that biological communities adjust to their physical position in the stream (Vannote et al. 1980). The smaller and narrower portions upstream receive a larger amount of CPOM in the form of leaf litter because they are closer to the riparian vegetation. As the stream widens it decreases the density of CPOM because it gets farther away from the riparian vegetation (Vannote et al 1980, Jonsson et al. 2001). This change in density of leaf litter leads to a change in the communities of organisms present (Vannote et al 1980, Jonsson et al. 2001) because, as previously stated, communities adjust to the physical conditions of the streams. The greatest abundance of shredders has been found in the narrow parts of the streams because of the high density of CPOM (Vannote et al. 1980).

Organic matter processing depends on several factors, including the width, depth, velocity, water flow, and temperature of the stream (Vanoote et al 1980 and Jonsson et al. 2001). Any alteration to these physical characteristic of the stream can cause a change in the abundance and or composition of benthic invertebrates thereby affecting the quality and amount of resources for organisms further down the stream (Jonssson and Malmqvist 2005). Therefore, any changes that affect the composition, diversity, or density of shredders upstream, will affect organisms in trophically linked functional guilds downstream (Vannote et al 1980). Experimental manipulations of both CPOM and macroinvertebrate communities demonstrate the importance of organic matter processing in the headwaters. When leaf litter is prevented from falling into a stream, shredding organisms suffer significant declines that in turn lead to declines in the abundance of filtering insects and invertebrate predators (Wallace et al. 1997).

Numerous studies have looked at the importance of diversity between functional guilds but only a few have examined the effect of species diversity within a functional guild (Jonsson and Malmqvist 2000). Several theories have been stated about the relationship between species richness and ecosystem function (Lawton 1994). The redundant species hypothesis states that many species have the same role in the same trophic level and therefore the loss of one of them will have no effect since others will be able compensate for the missing species (Lawton 1994, Jonsson and Malmqvist 2000, Loreau 2004). The rivet hypothesis states that all species have an essential role in ecosystem functioning therefore the loss of any one of them will affect the ecosystem's performance (Lawton 1994, Jonsson and Malmqvist 2000). The idiosyncratic hypothesis states that the ecosystem dynamics will change with species diversity but that the direction and magnitude of this change will be unpredictable because of the complexity ecosystems posses (Lawton 1994, Jonsson and Malmqvist 2000). In other words, it is known that organisms control ecosystem functioning but it is unclear and extremely difficult to determine what role species identity and diversity plays in the ecosystem dynamics.

Since shredders are significant FPOM producers, we will focus our attention on the importance of shredder species identity in organic matter processing. The following groups of macroinvertebrates will be utilized: isopods, amphipods and caenid mayflies. This experiment will consist of a mesocosm study system, in which we will simulate the environment in which these species live in order to study how the rate of organic matter processing and the quality of the fine particulate matter produced varies with species identity over time. Furthermore, we will examine how these factors vary in the treatments with more than one species present.

It has been seen that the loss or addition of species in the same functional guild show different impacts on the ecosystem dynamics (Walker 1992 and Lawton 1994); therefore I expect species identity within the shredder guild to play an important role in organic matter processing. I predict that the different species studied in this experiment will show a different CPOM processing rate and that the FPOM produced will differ in amount and size. This will correlate with past studies, in which it was observed that shredder species differ in their rates of organic matter processing (Jonsonn and Malmqvist 2005) and the fact that fecal matter may exhibit a great deal of diversity in regards to size, shape, and nutrient content between species (Wotton and Malmqvist 2001). These differences may affect the survival or growth of other groups in the food chain, therefore playing an essential role in the ecosystem processes and demonstrating that species within this functional guild may not be redundant. I also predict that rate of CPOM processing and that the amount and size of FPOM produced will be affected by the presence of other species of shredders because past results show that shredders can be more efficient in breaking down leaf litter when they are together with other species via facilitation (Jonsson and Malmqvist 2005, Dangles and Malmqvist 2004). With this experiment I plan to test the following hypotheses:

1) The organic matter processing rate will be different among treatments.
2) Each macro invertebrate species will show a different rate of production and size of fine particulate organic matter.
3) Species richness across treatments will affect organic matter processing and fine particulate matter production.

Methods

The shredder macroinvertebrates used for this study are isopods (labeled as I) of the genus *caecidotea*, amphipods (labeled as A) of the genus *hyalella*, and ephemeropterans of the genus *caenis* (labeled as M). I obtained these organisms from Brown Creek located on the University of Notre Dame Environmental Research Center in the Upper Peninsula of Michigan. The speckled alder tree is the dominant riparian tree species in this stream. For this reason, the leaves used

Following this, we performed a selection of ten average sized individuals who were dried and weighed. This was done in order to obtain an average weight of each macroinvertebrate species, and then be able to determine a standardized shredder biomass per treatment in each mesocosm.

Next, the mesocosms were prepared. I used small plastic containers oxygenated by an air stone and stored in an environmental chamber at $10^{o}C$ – $15^{o}C$ to simulate the natural environment of the species studied. I added filtered stream water and 0.3g of dry speckled alder leaves to each container. All mesocosms prepared were identical according to these conditions. These containers had a gathering of the different shredders, maintaining biomass constant but varying in species identity. I prepared seven different treatments in which three of them were single species treatments (A, M, I) and the other four were constituted by the 4 possible combinations between the three species studied (IM, AM, AI, MAI). Another treatment with no animals was prepared to determine the mass lost by the leaves during the leaching period. Each treatment had 10 replicates, therefore in total there were 80 containers.

The experiment had a total duration of 35 days. During the first five days the leaves where left in the containers with stream water to leach nutrients. After that period, I changed the water in each container and added the necessary number of specimens to the containers to prepare the seven treatments. In ten of these containers, the remaining leaf litter was dried and weighted in order to determine the average mass lost during the leaching process. The other 70 mesocosms, were placed in the environmental chamber at a temperature of 10℃-15℃. Every six days for 30 days, I removed two replicates from each treatment. The leaves were removed, dried and weighted. The water from each mesocosm was filtered through a 125µm and a 63µm sieve to sort the FPOM matter produced by size. Then it was dried and weighed.

On day 15, the water in the mesocosms was changed and all the dead organisms were taken out of each mesocosm and replaced. In order to be able to keep the FPOM already produced, the water was filtered through a 63µm sieve and added again to each mesocosm.

Statistical Methods

To analyze my data and test my hypotheses I used the programs SYSTAT 12. In order to test the effect of species identity on the rate of organic matter processing, I carried out an ANCOVA test including all seven species treatments with organic weight as a dependant variable and the time elapsed as a covariant. I also carried out an ANOVA test comparing the final organic matter weight of all the seven treatments with each other. In this test the dependent variable was the final organic matter weight and the factor was the treatments realized. I performed another ANCOVA test including all seven species treatments, with the fine particulate matter weight as a dependant variable and the time elapsed as a covariant, to determine the effect of species identity on the production rate of FPOM. In addition to this, I carried out two ANOVA tests to compare the proportions of the sizes of FPOM produced between all seven treatments. In these two the dependant variables were the proportion of FPOM of size 63µm or 125µm, and the factor was the different treatments carried out. I also performed a two sample T-Test with the organic weight as the selected variable and the treatments with or without amphipods as the grouping variables to compare the final organic weight between the treatments with amphipods and those without amphipods. Another two sample T-test was carried out to compare the proportions of 63µm and 125 µm fine particulate sizes with the presence or absence of amphipods in the treatments. In this test the grouping variable is the treatment with or without amphipods and the selected variable was the proportion of FPOM either of 63 µm or 125 µm.

Results

The organic matter weight decreased as time elapsed in each treatment as expected (Fig. 1). Even though each treatment showed a different rate on organic matter processing (Fig. 1), the ANCOVA test carried out showed that this difference was not significant (p-value = 0.8988, f-ratio = 0.364, square multiple R-value = 0.472). The raw data also showed a difference in the final organic weight of each treatment (Fig. 2) but the ANOVA test showed that this difference is not significant (p-value = 0.555, f-ratio = 0.878, square multiple R-value = 0.429). The raw data also showed that every treatment had a different FPOM production rate (Fig. 4) but the ANCOVA test showed that this difference was also statistically insignificant (p-value = 0.516, f-ratio = 0.879, square multiple R-value = 0.649).

The graph comparing the fine particulate sizes across treatments showed that each treatment produced different proportions of 125 μm and 63 μm particulates (Fig. 5). The ANOVA test carried out showed that the difference of the proportion of FPOM 63 μm between treatments was not significant (p-value = 0.287, f-ratio = 1.555, square multiple R-value = 0.571). The difference of the proportion of FPOM 125 μm was also not significant in an ANOVA test (p-value = 0.287, f-ratio = 1.555, square multiple R-value = 0.571).

Figure 1 shows that amphipods have the highest organic matter processing rate because the slope has the highest value in comparison to the rest of the treatments (slope = 0.2224). Figure 3 showed that amphipods played an important role in organic matter processing treatments because the final organic weight of the treatments with amphipod had a lower value than those without amphipods.

The two sample T- test showed that this difference caused by the amphipods was statistically significant (p-value = 0.090 and t = 2.088). The bar graph in Figure 6, showed that amphipods showed a more distinguishable difference in the size of the FPOM produced since the 125 µm FPOM produced was in a larger proportion in comparison with the one produced in the other treatments. The two- sample T-tests carried out showed that this difference in FPOM size production between treatments with or without amphipods is statistically significant (p-value = 0.027 and t = 2.610). Since the relationship between these fine particulate sizes is inversely proportional the other two-sample T-test also showed the statistically significant relationship between FPOM size and amphipod presence between treatments (p-value = 0.027 and t = 2.610).

Discussion

I was not able to statistically demonstrate that species identity plays an essential and significant role on organic matter processing and on fine particulate matter production. I think most of my data was not statistically significant because of the lack of replicates since it has been seen that a sufficient degree of replication has to be performed in order to be able to show the effect of diversity on organic matter processing (Dangles and Malmqvist 2004). Despite this, my raw data did show some interesting relationships that merit further research. Every treatment showed a different rate of organic matter processing and a different total final organic weight which indicates that species identity may play a significant role in the CPOM processing. This can be seen in the individual treatments of mayflies, isopods and amphipods which all showed different values of final organic weight (Fig. 2) and a different rate of CPOM processing (Fig. 1). Also these treatments differed in the FPOM production rates (Fig. 4) and the proportions of the particulate sized produced. All of the treatments produced a larger proportion of 125 um FPOM than 63 um FPOM (Fig. 5). Comparing the individual treatments we can point out that amphipods and isopods produce 125um FPOM in larger proportions than the mayflies (Fig. 5), showing that each species breaks down organic matter in different sizes and at different amounts. These results lend credence to past studies in which different shredder assemblages were shown to have different decomposition rates (Jonsonn and Malmqvist 2005).

In this experiment, I was able to demonstrate that some species have a more significant role than others on organic matter processing and on fine particulate matter production. Amphipods have the fastest organic matter processing rate and the most significant effect over CPOM processing and FPOM production in the treatments performed. When comparing the final organic weight of the treatments with amphipods with the treatments without amphipods, I could see that amphipods play an important role in CPOM processing. Treatments with amphipods present show a lower final organic weight than the treatments without amphipods (Fig. 3). In addition, amphipods showed to produce a higher proportion of 125 FPOM particles in comparison with other treatments (Fig. 6). These results show that some species posses certain traits that make them have a larger effect and therefore, a significant impact on their communities and on their ecosystem performance. Amphipods are capable of increasing the rate of organic matter processing and driving it to the production of larger sized fine particulates.

The importance of amphipods to organic matter processing may explain why I was not able to demonstrate an effect of species richness on organic matter processing and fine particulate matter production. In the raw data, the treatments with two or three species did not show a noticeable increase in the rate of organic matter processing from the single species treatments (Fig. 1). In past studies, species richness was shown to affect the rate of organic matter processing since different species appear to benefit form each others activities (Jonsson and Malmqvist 2000). It would seem that higher species richness lowers intraspecific competition, therefore; increasing feeding efficiency and increasing the organic matter processing rate (Jonsson and Malmqvist 2000). Because *hyalella* is a dominant species whose presence or absence is more important than other shredding macroinvertebrates I am able to provide an example where species richness does not produce the patterns that Jonsson and Malmqvist found on their study of species richness. Additionally, the fact that they used organisms from the same order and I used a wider range of organisms in my study, may account for the difference in the patterns observed.

Among the possible errors that could have caused my results to differ with past studies is that I did not keep track of the mortality experienced by some of the organisms. It was clearly seen that mayflies suffered from a much higher mortality rate than the isopods or amphipods, possibly affecting the organic matter processing and my results. For these reason, I would also recommend a better selection of study organisms because the mayflies are extremely sensitive animals for survival under laboratory conditions. I also believe that if this experiment was performed on a longer time period the data would have shown more uniformity and normality expressing the real organic matter processing rate. The use of a micro-scale measuring system could have provided better weight measurements. In addition, the preference of the shredder macroinvertebrates for the different CPOM available could be studied to demonstrate other differences among species.

The fact that species identity does play an important role within the shredding functional guild on the ecosystem function tells us that species are not redundant within this feeding group and therefore; the loss of any species would change the stream dynamics in an unpredictable way. For these reasons, the study of species identity in freshwater ecosystems should be continued since these organisms control the stream dynamics, organic matter processing, energy flow and nutrient cycling of the freshwater ecosystems. It is known that the demand for water supply is in a continuous increase due to population growth and climate changes (Covich et al. 1999). Also, it is recognized that global ecosystems cannot function without the supply of inland waters (Covich et al. 1999). Benthic species are responsible for the quality of fresh water supply (Covich et al. 1999). Therefore, it is imperative to study the importance of species richness and identity on ecosystem function before changes in these ecosystems result in unexpected and unwanted consequences.

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Figures

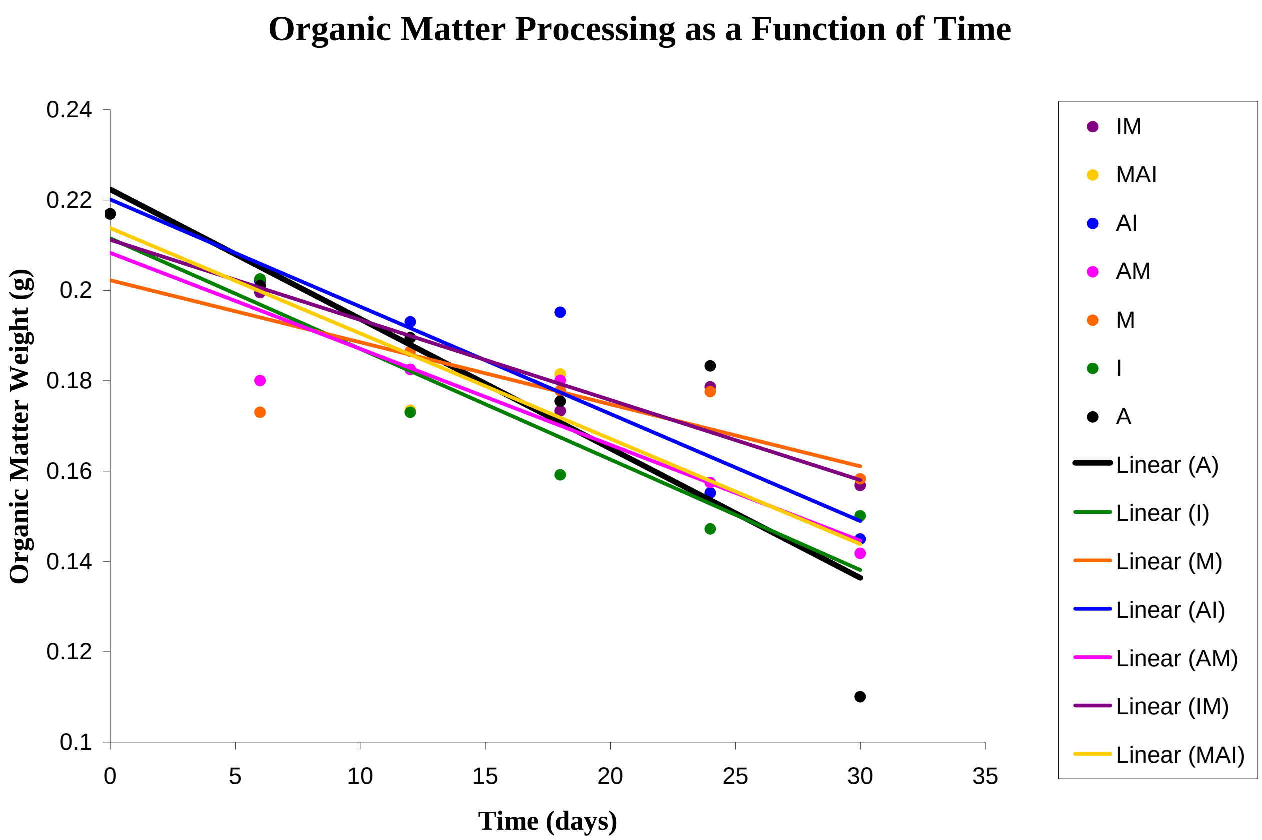

Fig.1 The organic matter weight decreased as time elapsed in each treatment. Each treatment showed a different rate on organic matter processing.

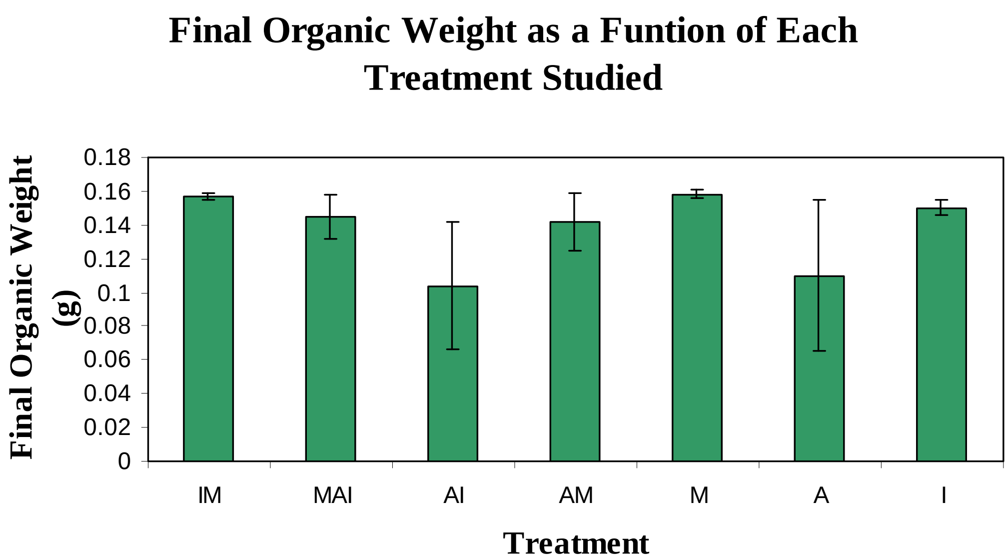

Fig. 2 Every treatment showed a different final organic weight.

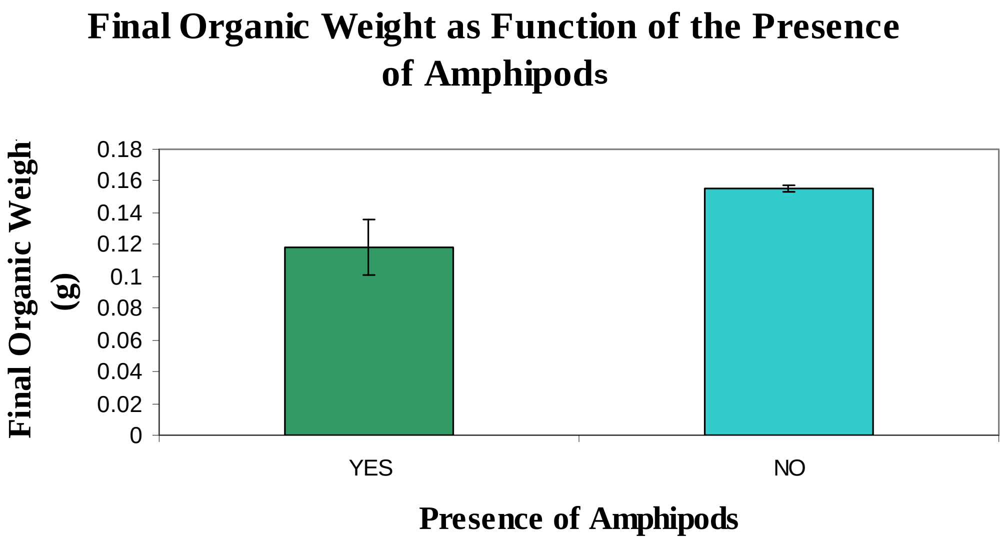

Fig. 3 Treatments with amphipods resulted with a lower final organic weight than those without amphipods.

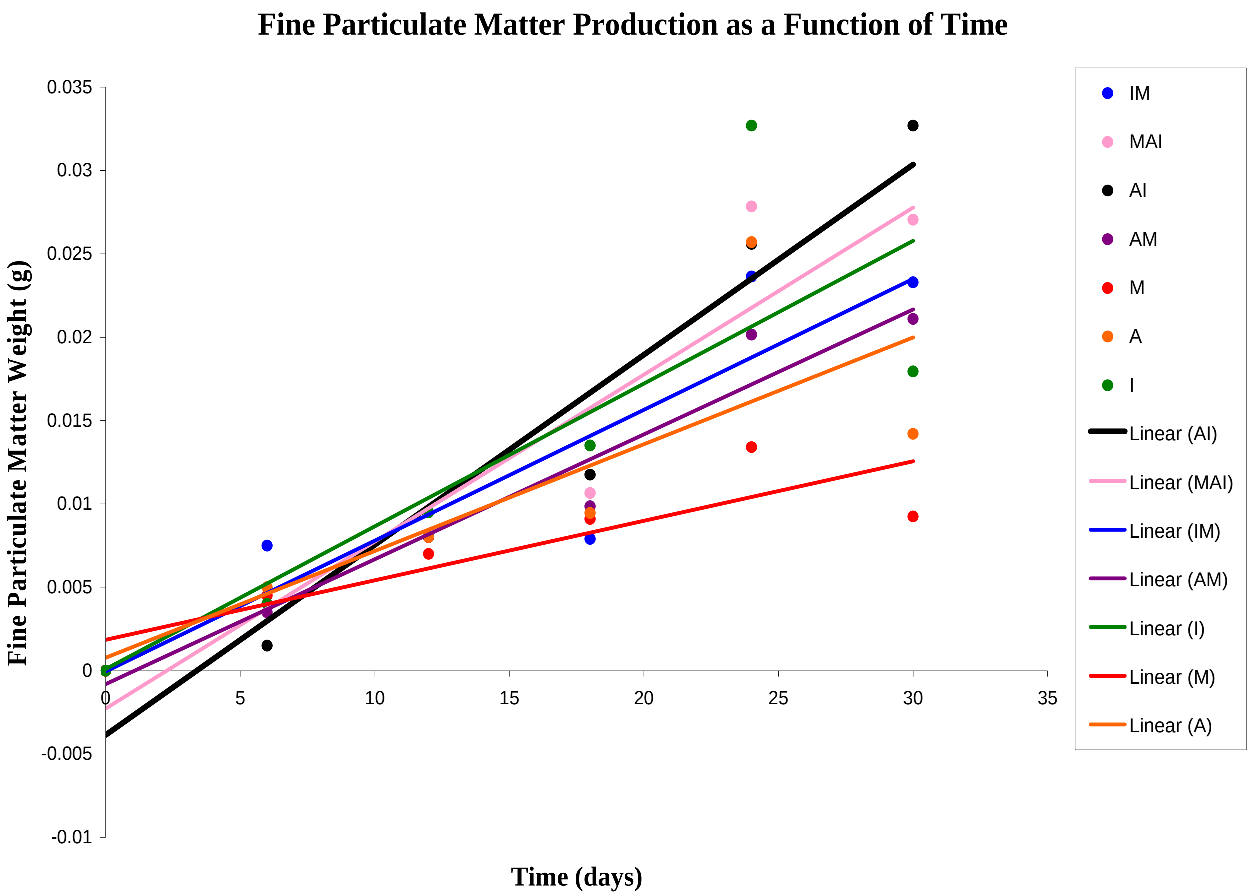

Fig. 4 Every treatment showed a different FPOM production rate

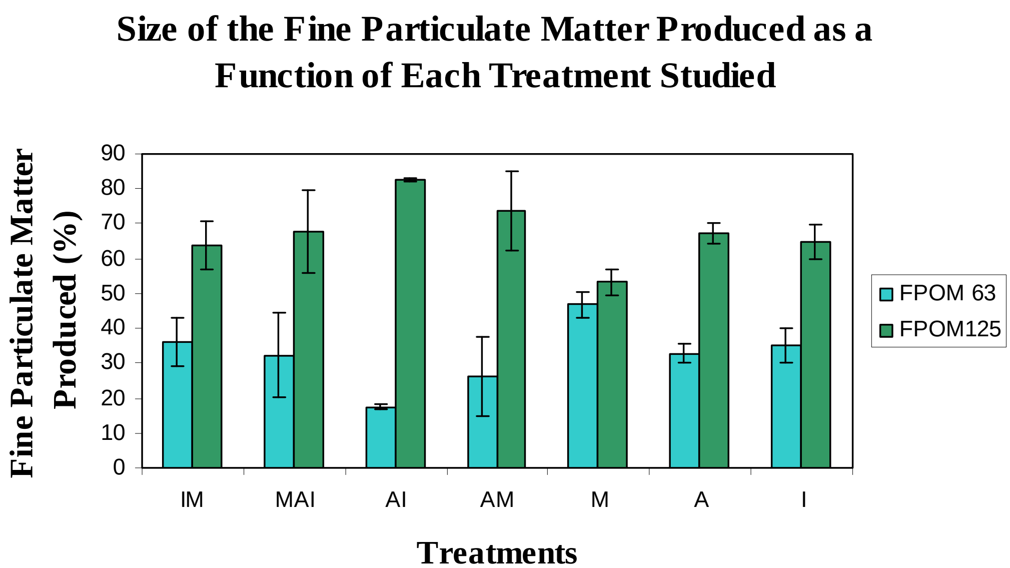

Fig. 5 Each treatment produced different proportions of 125 μm and 63 μm fine particulates.

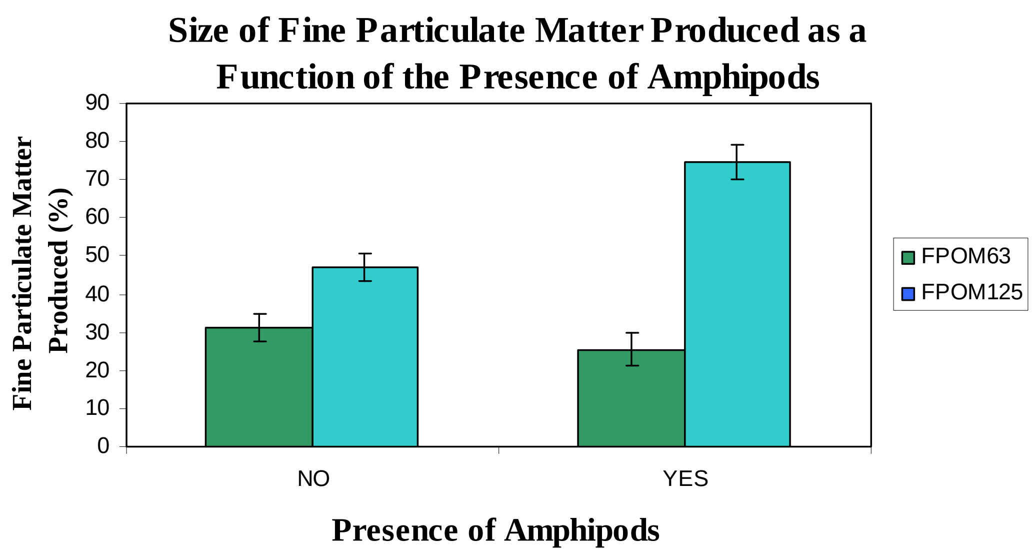

Fig. 6 Amphipod treatments showed a more distinguishable difference in the sizes of the FPOM produced. The 125 µm fine particulates produced are in a larger proportion in comparison with the ones produced in the non-amphipod treatments.