FACILITACIÓN ENTRE CAMARONES Y EFEMEROPTEROS EN ECOSISTEMAS DE ARROYOS DE MONTAÑA, PUERTO RICO

FACILITATION BETWEEN SHRIMPS AND MAYFLIES IN MONTANE STREAM ECOSYSTEMS, PUERTO RICO

Adriana Marcela Forero Céspedes[1], Pablo E. Gutiérrez Fonseca[2], Alonso Ramírez[3]

1. PhD student. Department of Biology, Zoology Research Group, University of Tolima. E-mail: adrianam@ut.edu.co
2. Post Doctoral Researcher. Department of Environmental Sciences, University of Puerto Rico. E-mail: gutifp@gmail.com
3. Ph.D and Professor. Department of Environmental Sciences, University of Puerto Rico. E-mail: aramirez@ramirezlab.net

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*Correspondencia del autor: Adriana Marcela Forero Céspedes. Department of Biology, Zoology Research Group, University of Tolima. E-mail: adrianam@ut.edu.co

RESUMEN

La facilitación es un tipo particular de interacción interespecifica, donde una de las especies participantes se beneficia de la presencia de otra. En Puerto Rico, se sabe que los camarones tienen fuertes interacciones con otros componentes de la comunidad, ya que pueden eliminar sedimento fino y detritos que normalmente se acumulan en las rocas y promover el establecimiento de comunidades de algas. Los efemerópteros, generalmente se benefician de las actividades del camarón ya que le facilitan el acceso a los recursos alimenticios. En la Estación de Campo de El Verde incubamos losetas en arroyos artificiales para obtener biofilm y después realizamos los siguientes tratamientos: (1) control, que contenía sólo las losetas; (2) efectos de camarón, que contenían losetas y camarones *Atya lanipes*; 3) control más sedimentos, donde agregamos sedimentos para cubrir las losetas, y (4) camarones más sedimentos, donde agregamos *Atya lanipes* después de añadir losetas y sedimentos. Medimos la cantidad de materia organica (como ash-free dry mass, AFDM) y concentración de clorofila *a* y estimamos las respuestas de crecimiento de los efemerópteros en cada tratamiento. Nuestro estudio muestra que las actividades de forrajeo de camarón facilitan el acceso de los efemerópteros a los recursos alimenticios.

Palabras claves: Facilitación, camarones, efemerópteros, AFDM, Clorofila

ABSTRACT

Facilitation is a particular type of interspecific interaction, where one of the participating species benefits from the presence of the other. In Puerto Rico, shrimps are known to have strong interactions with other components of the community, because they can remove fine sediments and detritus that normally accumulate on rocks and promote the establishment of algal communities. Mayflies, generally benefit from the activities of shrimp because facilitate access to food resources. We desing one experiment with several treatments with and without sediment and with and without shrimp to assess whether shrimp foraging activities facilitate mayfly access to food resources. At El Verde Field Station we incubated tiles in artificial streams to obtain a biofilm layer, and after assigned to a particular manipulation: (1) control, which contained only the tiles, (2) shrimp effects which contained tiles and *Atya lanipes shrimps*, (3) control plus sediments, where we added sediments to cover the tiles, and (4) shrimp plus sediments, where we added *Atya lanipes* after adding tiles and sediments. We measure organic material (as ash-free dry mass, AFDM) and chlorophyll *a* concentration and we estimate mayfly growth responses in each treatment. Our study shows that shrimp foraging activities facilitate mayfly access to food resources.

Keywords: Facilitation , Shirmps, mayfly, AFDM, Clorophyll *a*.

INTRODUCTION

Aquatic communities in Puerto Rico are dominated by decapods (1; 2). Within this group, shrimps are important components of stream ecosystems, because their feeding activities result in both consumption and disturbance of the particles accumulated in the stream bottom and their presence have major effects on benthic environments (2).

Tropical stream research has shown that shrimps can remove fine sediments and detritus that normally accumulate on rocks and promote the establishment of algal communities, dominated by surface-attached diatoms (1; 3; 2). Likewise, they play an important role determining the composition and density of insect assemblages, as they can impact insects directly via predation and competition, and indirectly through removing particles from the water column (4).

Shrimps can remove fine sediments indirectly, via body movements, as they move over substratum surfaces causing sediments to be swept into the water column. They also act directly, via removal of sediments through brushing and/ or picking with feeding appendages, whereby sediment particles are either rejected or swept downstream and also they can eat them (1). Within this group, *Atya lanipes* is one of the species that dominates streams in Puerto Rico (1, 5) and it is characterized by being both a scraper and filter feeder (6), and capable of scraping, brushing, filtering, and picking particles. These abilities allow individuals to exploit resources from both benthic surfaces and the water column. Atyid shrimps may affect patterns of sediment cover, algae and benthic insects (1).

In stream tropical streams, Ephemeroptera are generally abundant and benefit from the activities of shrimps (4). Previous studies have reported ephemeropterans to be more abundant in the presence of shrimps (1, 7, 8). Therefore, our overall goal was assess whether shrimp foraging activities facilitate mayfly access to food resources. We hypothesized that shrimp foraging would remove benthic sediment without altering the biofilm of the surface, which is the main food resource for Ephemeroptera nymphs.

Materials and methods

Study site: Experiments were run at El Verde Field Station, located within the Luquillo Experimental Forest (LEF) and main site of the National Science Foundation’s Long Term Ecological Research Program (i.e., LUQ LTER). The LEF is located in northeastern Puerto Rico (8°19’ 16, 83"N, 65°49’10, 13"W). Mean monthly precipitation ranges from 200 to 300 mm, where February through April are the drier months, but monthly rainfall is variable. Mean monthly temperatures range from 23.5°C in January to 27.0°C in September (9) and have an elevation at 350 m (10).

Puerto Rico has 18 species of freshwater shrimps, which correspond to three families Atyidae (11 spp), Xiphocarididae (1 sp) and Palaemonidae (6 spp) (2). Likewise, Puerto Rico possesses an abundant and diverse fauna of aquatic insects, being the order Ephemeroptera, Trichoptera and Odonata the best known (2). Streams at the LEF have 10 species of decapods, dominated by two species of freshwater shrimp: A. *lanipes* and X. *elongata* (5). Among aquatic insects, the order Ephemeroptera is one the most abundant and the family Leptophlebiidae are dominant (11; 4).

Experimental design: The experiment was run using a set of artificial streams that receive water directly from Buruquena Stream. We incubated tiles of 25 cm^2 for 40 days, to obtain a biofilm layer. To assess the effects of shrimp on benthic biofilms, we used plastic boxes in the artificial stream facility, each box contained 16 tiles pre-colonized with biofilms. Each box was assigned to a particular manipulation: 1. control, which contained only the tiles, 2. shrimp effects, which contained tiles and 10 *Atya lanipes* shrimps, 3. control plus sediments, where we added sediments to cover the tiles, and 4. shrimp plus sediments, where we added 10 *Atya lanipes* after adding tiles and sediments. We used 10 shrimp per box to create a density of 8.5 individuals per m^2, which is similar to densities reported for nearby streams (12). Sediment were 7 g/m^2. Shrimp were allowed to graze on tiles for 48hrs and then were removed from boxes.

Shrimp effect on biofilm biomass and chlorophyll *a* concentration: The surface of each tile was scraped with a brush and rinsed into beaker. We then added water until 300 ml of sample. We used Merck Millipore fiber glass filters, pre-combusted at 500 ° C for one hour, and weighed. Biofilm biomass was measured by filtering 150 ml of sample, oven drying the filters at 70°C for 24 hr, and then ashing them at 500°C for one hour to estimate ash free dry mass (AFDM). AFDM was expressed as g/m^2. Chlorophyll *a* concentration was measured by filtering the remaining 150 ml of sample and then measuring chlorophyll *a* following the methodology of Steiman *et al.* (13).

Mayfly growth responses: Tiles of different treatments were used as grazing substrate for mayfly nymphs. For this we used plastic containers where we placed a mayfly with a tile for three days in the artificial stream facility. Individual mayflies were measured (in millimeters) at the start and end of the experiment using gridded paper and the Image J program. Growth was expressed as (mg/mg/day).

Collection of organisms: Leptophlebiidae mayfly nymphs and individuals of the freshwater shrimp *Atya lanipes* (Decapoda: Atyidae) were collected from Buruquena, a first order stream, using D net by disturbing in stream habitats like riffles and pools. After the organisms alive, placed in an aerated plastic aquarium at the station.

Statistical analyses: We used PAST statistical software, version 3.14 (14) to run analysis of variance (ANOVA) and Tukey's test to assess whether AFDM and Chlorophyll a were significantly different among treatments.

Results

Biofilms in artificial stream

After 40 days, on the surface of the tiles, a biofilm was formed, registering an average value of 6.43 g/m^2 of AFDM and 11.4 $\mu g/m^2$ chlorophyll a at the beginning of the experiment.

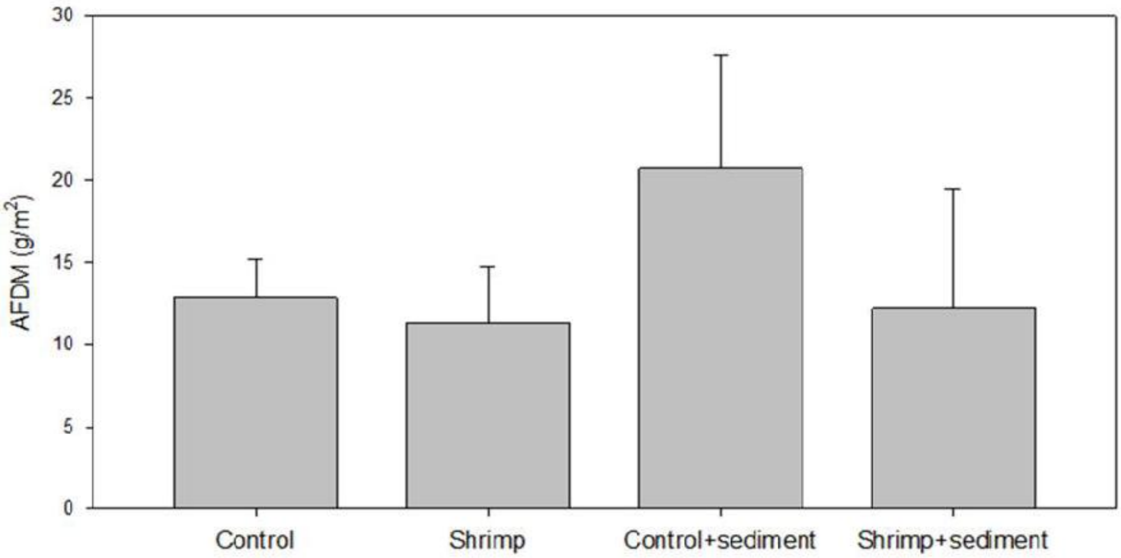
Shrimp effect on biofilm biomass and chlorophyll a concentration:

Biofilm biomass ranged from 9.84 g AFDM /m^2 to 16.32 g AFDM /m^2 in control treatments without sediment and 10.80 g AFDM /m^2 to 34.72 g AFDM /m^2 in control treatments with sediment. Treatments showed that the presence of shrimp did not change the quantity of organic matter accumulated on tiles. However, shrimp played a significant role reducing the amount of sediment added experimentally to the tiles (ANOVA, $F = 5.071$, $p = 0.006$). Shrimp activity reduced biomass to 20.7 g AFDM /m^2 to 12.2 g AFDM /m^2 (Tukey's test indicates that control + sediment is different to the rest) (Figure 1).

The clorophyll *a* ranged from 301.68 $\mu g/m^2$ to 165.76 $\mu g/m^2$ in control treatments without sediment and 301.68 $\mu g/m^2$ to 145.87 $\mu g/m^2$ control treatments with sediment. Treatments showed that the presence of shrimp does not change the amount of chlorophyll a that accumulates on the tiles. Similar, experimental addition of sediment also has no significant effect on chlorophyll *a* (ANOVA, $F = 0.46$, $p = 0.71$) (Figure 2).

Mayfly growth responses:

The size of the mayfly at the start of the experiment ranged 5.8 mm to 7.3 mm. They are placed individually with the tiles, and we observed that they interacted



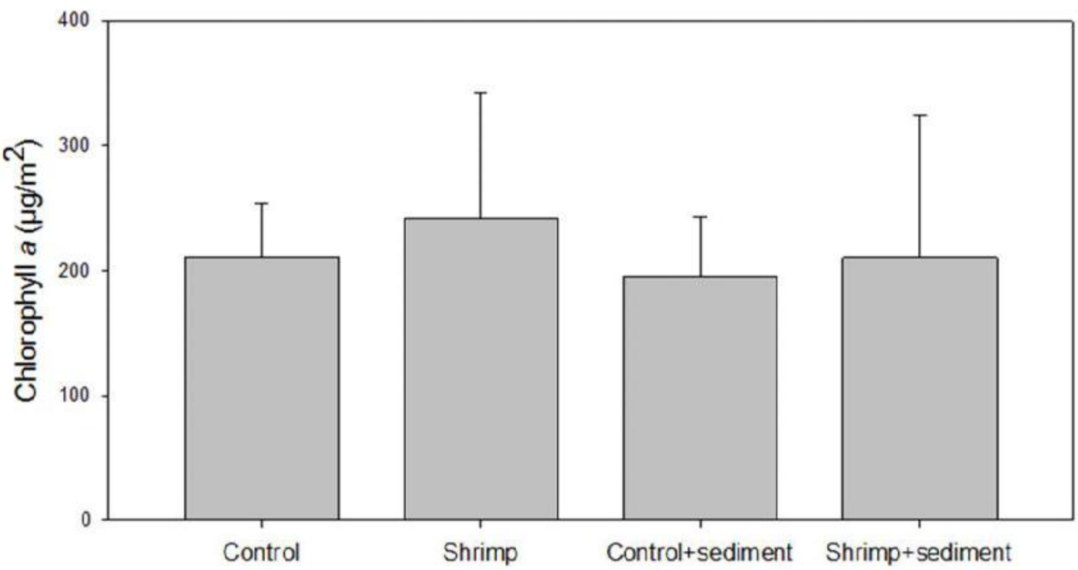


Figure 1. a) AFDM per treatment. b) Chlorophyll *a* per treatment.

directly with the biofilm of the surface of tile, with the nights being the most foraging activity. In the treatment with sediment, we observed a foraging activity of the lowest mayfly. Most treatments resulted in negative Growth, except for the tiles that were exposed to shrimp and not to sediments. We did not do statistics, as all but one treatment had negative growth rates.

Discussion

Our study found that shrimp foraging activities result in benefits for mayfly nymphs, supporting our original hypothesis that shrimp foraging would remove benthic sediment without altering the biofilm of the surface, which is the main food resource for Ephemeroptera nymphs.

Shrimp effects on organic matter.

Modified legs of *Atya lanipes* are able to remove fine or particulate sediment that accumulates on the substrate, such as the sediment we added. They have the capacity to rapidly remove sediments and detritus deposited on benthic substrata (1). In our experiment, shrimps did play an important role reducing benthic biofilm biomass, because they do have an effect on matter more

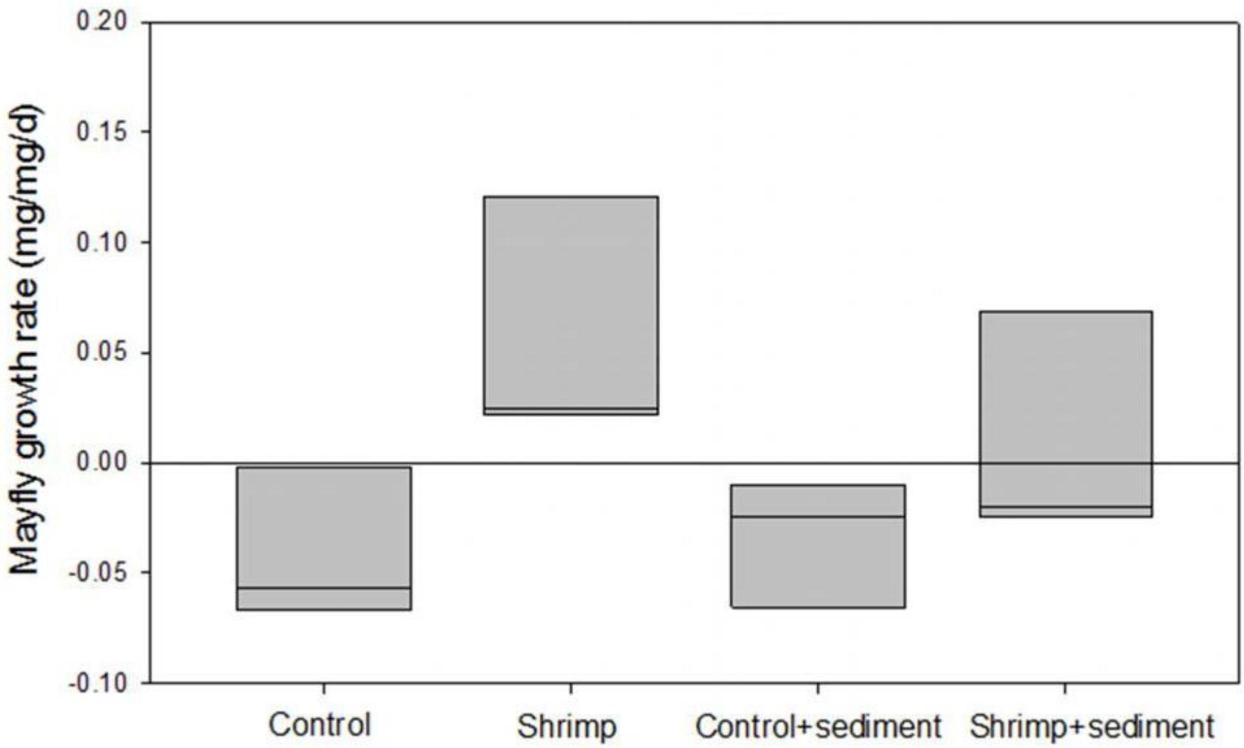


Figure 2. Mean mayfly growth rates with and without shrimp and with and without sediments

strongly attached to the substrate, such as organic matter and other components of the biofilm, this agree to that mentioned by Pringle and Blake (15), Pringle (3), Pringle *et al*. (16), March *et al*. (7), Macías *et al*., (17), Ramírez and Gutiérrez-Fonseca (2) who suggest atyid shrimps helps reduce sediments of streams in Puerto Rico (8).

Shrimp effects on chlorophyll a

It is well known that atyid shrimps interact strongly with periphyton and sediments of streams in Puerto Rico (8). Atya shrimps are general particle consumers of particles that accumulate on the bottom of the stream or that move in the water column, decreasing directly algal standing crop, species richness and structural complexity, maintaining an understory community dominated by sessile algal taxa (1). In contrast, streams without shrimp, the benthic substrate tends to accumulate fine particles, have communities of algae characterized by filamentous algae and mobile diatoms (2, 3).

However, in our experiment they were effective in reducing the amount of particles on the substrate, but this change did not translate into changes in the amount of chlorophyll *a* in the biofilm. This suggests that the shrimp did not consume an appreciable amount of algae in our experiment, possibly because these organisms are more adapted to cleaning the substrate (8) than our experimental tiles. This contrasts with others studies in the LEF streams that showed that shrimps reduce algal biomass and alter algal community composition (15; 3; 16).

Effect of changes caused by shrimp and sediment on Ephemeroptera.

Ephemeroptera are scrapers, which prefer clean sediment substrates and algae. Thus, it is not surprising that sediment treatment was not favorable. Although the amount of chlorophyll *a* did not change among treatments, the presence of shrimps appear to be a key factor for Ephemeroptera, as they remove the sediment and allow for better access to benthic diatoms. Thus, shrimp facilitate access to resources or improve the quality of the biofilm for Ephemeroptera, resulting in better growth, are not adversely affected by shrimp and may be indirectly facilitated (1)

Conclusions

Facilitation often aids in maximizing resource utilization by consumers. Shrimps and mayflies are clearly interacting with each other, with shrimp foraging activities facilitating mayfly access to food resources, the quality of those resources and potentially increase their population success. Therefore, the presence of these two organism at the same time benefits the dynamics in tropical streams ecosystems in Puerto Rico

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