

Exploring effects of proliferation of *Didymosphenia geminata* on abundance and coexistence of *Rhyacophila* species (Trichoptera) in streams near the Rocky Mountain Biological Laboratory

Abstract

Coexistence of closely related species can be explained by several biotic and abiotic factors. The patterns of coexistence of the species of the genus *Rhyacophila*, (Trichoptera) in streams near the Rocky Mountain Biological Laboratory (RMBL) has been tracked for 45 years. This study is a continuation from previous undergraduate studies from 2017- 2019 to explore the mechanisms explaining patterns of coexistence of these caddisflies. Studies in 2017 and 2018 considered coexistence factors at the scale of stream reaches, and in 2019 we explored microhabitat preferences within stream reaches by different species of *Rhyacophila* and resource partitioning of prey by these predatory caddisflies. One important factor we have not yet considered to explain the abundance or coexistence of *Rhyacophila* species is the proliferation of *Didymosphenia geminata* (*Didymo*), a native colonial diatom whose growth form varies from low flow years where it creates large benthic mats in oligotrophic streams, and high flow years where it can experience scouring and will not proliferate as it does in low flow years. This variation in flow among years is one of the observed effects of climate change; and with a long-term trend of reduced snowpack, earlier spring thaw and lower flow, we expect *Didymo* blooms to become increasingly common. This year being a low flow year we asked; 1) Is abundance of any or all *Rhyacophila* species affected by habitat alteration by *Didymo* blooms: positively (if they use it as a refuge from the flow) or negatively (if it impedes their foraging for prey or access to highly oxygenated microhabitats)? Previous results showed all *Rhyacophila* species prefer areas of higher flow that have more dissolved oxygen, which would produce a negative relationship with *Didymo* blooms that slow the flow near the substrate surface where *Rhyacophila* forages. Previous results showed all *Rhyacophila* species prefer areas of higher flow that have more dissolved oxygen, which would produce a negative relationship with *Didymo* blooms that slow the flow near the substrate surface where *Rhyacophila* forages. 2) If food abundance is high in *Didymo* samples, then can we expect greater abundance of any *Rhyacophila* species in samples with more *Didymo*, 3) especially species or instars with small mouth gapes that prefer chironomids as prey, which are more abundant in large *Didymo* blooms? We addressed those questions by continuing surveys of macroinvertebrates in eight streams near RMBL, estimating *Didymo* biomass at the microhabitat and macrohabitat scales, and evaluating diet and habitat (*Didymo*) preferences of coexisting *Rhyacophila* species. Results demonstrated that total *Rhyacophila* increased in abundance at sites with greater *Didymo* biomass, primarily due to increases in abundance of the species that aggregate at sites and samples with more chironomids (*R. alberta*, *R. hyalinata*, *R. brunnea*), which are prey that prefer high *Didymo* microhabitats. These results are consistent with food as the major driver of *Rhyacophila* habitat preferences. Mouth gape widths and instar of *Rhyacophila* did not vary with preferences for *Didymo*. We conclude that *Didymo* will continue to proliferate with climate change which might favor species of *Rhyacophila* that prefer chironomids as prey.

Introduction

The ranges of many species, both terrestrial and aquatic are being affected due to climate change. Therefore, it is important to understand the factors affecting the distribution and abundance of species in a changing world. The choice of species' niche is affected by multiple aspects of its environment, including food resources, predators, and habitat features influencing their fitness. (Tingley et al. 2009). The movement of species to occupy new ranges can give clues to the effects as climate change continues.

In addition, with niche alterations that may be associated with climate change, new combinations of species may come into contact, potentially leading to competition between those species for resources. Such competition can be avoided by partitioning space, food resources or development time (Grinnell, 1917). In some cases, dominant species can outcompete other species, occasionally resulting in high stakes reductions in fitness, like intraguild predation (Sparrow-Scinocca, 2017). The central focus of studies by undergraduates at RMBL over the past three years has been to further our understanding about how some closely related species that are potential competitors are able to coexist while others do not.

One hypothesis explaining coexistence of closely related species is that partitioning food sources can reduce the negative effects of potentially competing species (Lavandier and Cereghino, 1995). Consequences of not enough resources for early instar stonefly larvae could result in smaller females who need more fat to produce eggs (Peckarsky and Cowan, 1991). The inferior competitors will be smaller while superior competitors become larger; and in some cases competing for the same prey may lead to intraguild predation for resources. For example, two predatory invertebrates, *Sweltsa onkos* (a stonefly) and *Rhyacophila velox* (a caddisfly) were studied in a controlled environment where *R. velox* consumed *S. onkos* when the abundance of *S. onkos* was high (Sircom and Walde, 2009)

Species of the genus of caddisflies, *Rhyacophila*, prefer to inhabit cold, fast-moving, and highly oxygenated streams, although those specific niche requirements can vary among species. Studies conducted on patterns of coexistence in *Rhyacophila* (in 2017 by Bridgett Sparrow-Scinocca, and in 2018 by JaHyun Yang) revealed that many closely related species of *Rhyacophila* were found in the same streams near RMBL. Anywhere from, two, three, four, five, and sometimes six species of *Rhyacophila* larvae were found together. However, some streams typically have only one species. Different species of *Rhyacophila* in the Gunnison basin have specific elevation preferences, but some species overlap in elevation, for example, *R. coloradensis*, and *R. hyalinata* (Dodds and Hisaw, 1925). These two species were observed in similar altitudes between 6,000 -11, 000 ft. The researchers attributed preferences in altitude of streams to temperature needs because, higher altitude streams are generally colder than those at lower elevations.

Previous studies conducted in 2017 – 2019 by undergraduates in the education program have provided important background information about the biology and coexistence patterns of the four most abundant species of *Rhyacophila* in streams around RMBL. Those studies focused on the macrohabitat scale of stream reaches (water temperature, temperature-specific conductivity, stream size, discharge, predator density and competitor density; Sparrow-Scinocca 2017, Yang 2018), and the microhabitat scale (water depth, current velocity, substrate particle size) (Ruiz 2019). *R. alberta* and *R. hyalinata* were frequently found together at high elevation,

smaller, colder streams with low conductivity. *R. hyalinata* negatively affected the growth rate of *R. alberta*, but the superior competitor also consumed *R. alberta* (intraguild predation) (Sparrow-Scinocca, 2017). Coexistence was observed in *R. brunnea* and *R. valuma*, which were found together in lower elevation, larger, warmer streams with larger substrate particle sizes (Yang, 2018). Microhabitat differences were observed and the potential for partitioning of food resources of *Rhyacophila* that coexisted at the same sites (Ruiz 2019). However, the effects of proliferation of the nuisance diatom (*Didymosphenia geminata*) were not explored due to a high flow year in which *Didymo* proliferation was very low.

Didymo grows long, polysaccharide stalks that proliferate into algal mats that cover the bottom of streams, to compete for limited phosphorus (Whitton et al, 2009). *Didymo* blooms can attract chironomids, as well as other organisms in the *Rhyacophila* diet, such as oligochaetes (Bray et al, 2020). If abundant *Didymo* attracts chironomids, then it could likewise increase food resources for these predatory caddisflies (Gillis and Chalifour, 2009), as chironomids are one of the favored prey items for *Rhyacophila* (Thut, 1969). Some mayflies (e.g., *Baetis*), which are another food source for *Rhyacophila*, may be unaffected by *Didymo* proliferations (Brogan 2020). However, the effects of *Didymo* on these caddisflies (negative or positive) is yet to be determined.

While habitat changes caused by *Didymo* blooms may be beneficial to *Rhyacophila* by causing prey aggregations, those changes may be a problem for trout who reduce growth rates as communities shift from mayfly-dominated to chironomid-dominated (Taylor, B. W., unpublished data), and become infected with whirling disease, which uses some oligochaetes as an intermediate host (Markiw et al, 1983). It is possible that the recent environmental changes (e.g., protracted drought), which affect the extent of *Didymo* proliferation, could cause a shift in the ranges of these caddisflies. The conditions of the streams where *Didymo* proliferates may affect the suitability of habitat for *Rhyacophila* species and other benthic macroinvertebrates (Burgmer, T., 2007). Species composition and the relative abundance of this and other diatom taxa are effectively used as indicators of changing environmental conditions (Taylor and Bothwell, 2014). Investigating the relationship between *Didymo* proliferation and the distributions of *Rhyacophila* species could give some clues as to why some species do or do not coexist in streams around RMBL.

The goal of this study was to test the following hypotheses: 1) If habitat is the critical effect of *Didymo* on *Rhyacophila*, then we expect abundance of all *Rhyacophila* species to be lower in streams or samples with more *Didymo*, because *Didymo* slows flows near the substrate of streams, thereby reducing dissolved oxygen, which is a critical environmental requirement for these caddisflies. 2) If food is the critical effect of *Didymo* on *Rhyacophila*, then we expect abundance of all *Rhyacophila* to be higher in streams or samples with more *Didymo*, because there are more chironomids and plenty of *Baetis* in *Didymo* blooms. 3) We expect *Rhyacophila* species (e.g., *R. valuma*) or instars with smaller mouth gapes to prefer habitats with more chironomids, and consequently to be more abundant in streams or samples with *Didymo* blooms.

Study Sites

We sampled *Rhyacophila* from eight long-term stream sites in the Upper East River Basin of Gunnison County, Colorado (Figure 1). There are three sites on Copper Creek (Second Crossing, above Judd Falls, above the bridge in Gothic), four sites on East River (Oregon Mine Road Crossing, near Avery, near Levi Cabin, and above the bridge in Gothic), and one site on Rustlers Gulch (above the confluence with the East River). These sites are part of an unprecedented historical data set monitoring invertebrates since 1976 and provide an opportunity to look at long term trends. Streams have been sampled twice each summer, once during the early season and again in the later season to account for different phenologies of invertebrate species.

Methods

Collection Methods and Measurements of Didymosphenia geminata

We repeated collection methods as in previous years by using a Hoffman sampler consisting of a 0.104 m² area box fastened to a 364 μ m mesh drift net. Before disturbing the substrate to sample invertebrates, we estimated the percent cover of and height of *Didymo* using an Aqua Google™, a glass-bottomed viewing box placed inside of the Hoffman Sampler. This protocol provided *Didymo* biomass estimates at the microhabitat scale. Then substrates inside the box were disturbed for one minute and benthic invertebrates were swept by the current into the net. All Diptera, mayfly, stonefly, and caddisfly larvae were then sorted and identified in the field. We took four samples in different locations along each stream site. *Rhyacophila* specimens were preserved in vials of 70% ethyl alcohol for identification and further processing in the lab, including identification of stages (instars) of each individual. All other organisms were identified in the field and then released.

At the end of the summer we did annual surveys of *Didymo* at all 8 sites that have been carried out since 2013 to estimate an index developed by Brad Taylor (average percent cover times average height of *Didymo* growth at 3 transects), which provides a macrohabitat scale estimate of *Didymo* biomass that can be compared to the abundance of *Rhyacophila* species. At each site we estimated the percent cover and height of *Didymo* at three transects at half meter or one meter intervals (depending on the width of the stream) and averaged those values to obtain a macrohabitat estimate of *Didymo* biomass.

Data Analysis

To test whether *Didymo* biomass may explain the patterns of distribution of coexisting pairs of *Rhyacophila* species, we plotted the relationships between the abundance of each *Rhyacophila* species as well as the total density of *Rhyacophila* species versus the biomass estimates of *Didymo*. We did graphical analyses at a microhabitat scale (per sample) as well as the macrohabitat scale (per stream reach), as was done in previous studies. We calculated R² using X-Y scatterplots in excel to evaluate the strength of all relationships between *Didymo* abundance and density of *Rhyacophila* species to describe the strengths of the relationships between each species and this parameter. Using these plots, we also compared whether different species of *Rhyacophila* aggregated with different prey species and whether favorite prey species preferred microhabitats or macrohabitats with more *Didymo*.

Results

Total *Rhyacophila* abundance increased at sites with more *didymo* biomass but only at the macrohabitat scale (sites) (Figure 2a). This relationship was positive, but not strong ($R^2=0.4$), suggesting that the variation in *Didymo* biomass does not explain a high proportion of the variation in abundance of total *Rhyacophila*. This result was not consistent with the habitat hypothesis (1). In the 2019 study all *Rhyacophila* species preferred microhabitats with higher flow because they need the oxygen the high flows produce. If *didymo* slows down the flows near the surface of the substrate where *Rhyacophila* likes to be, then *Rhyacophila* should avoid *Didymo*, which would result in a negative relationship; however this was not what we observed. Therefore, we can rule out Hypothesis 1 (avoidance of *Didymo* as an inferior habitat).

In contrast, this pattern of total *Rhyacophila* abundance vs *Didymo* is consistent with hypothesis 2 (preference for habitats with more food). Chironomids increased with more *Didymo* at the scale of samples (Figure 3a), and at the microhabitat scale of sites (Figure 3b). Therefore, we expected species of *Rhyacophila* that aggregate in areas with more chironomids to also increase with *Didymo* biomass. In contrast, the other prey species preferred by *Rhyacophila* (*Baetis*) showed no relationship at the microhabitat (Figure 3c) and macrohabitat scale (Figure 3d). Thus, we expected *Rhyacophila* species that prefer *Baetis* to show weaker relationships with *Didymo*.

Before *Didymo* proliferated, at the macrohabitat scale, total *Rhyacophila* aggregated at sites with higher prey density (Figure 4a); but this pattern disappeared after *Didymo* bloomed. Specifically, three species of *Rhyacophila*, *alberta*, *brunnea* and *hyalinata*, were more abundant in samples and streams with more prey (Figures 4b, 4c, and 4d). The fourth species (*R. valuma*) showed no relationships with prey density (Figure 4e). Of the three species that aggregated with increasing prey densities, the strongest association with chironomids occurred for *R. alberta* (Figure 4b). *R. hyalinata* (Figure 4c) and *R. brunnea* (Figure 4d) showed stronger associations with *Baetis*, but also a weaker, but positive associations with Chironomids. If hypothesis 2 is correct, those three species should increase with *Didymo*, especially *R. alberta*.

Consistent with hypothesis 2, *R. alberta* abundance increased at sites with more *Didymo* (Figure 5a), but *R. hyalinata* (Figure 5b) had a weaker association with *Didymo*. In contrast, *R. brunnea* (Figure 5c) had an even weaker relationship with *Didymo* biomass, and *R. valuma* (Figure 5d) had no association with *Didymo* biomass. It is noteworthy that *R. valuma* and *R. brunnea* comprise more than half of the total number of *Rhyacophila* both before and after *Didymo* bloomed (Figure 6). Therefore, variation among effects of *Didymo* on the different species of *Rhyacophila* further weakens the overall response of total *Rhyacophila* to *Didymo* biomass.

Bar graphs of the mean sizes (mouth gapes) of all four species of *Rhyacophila* before and after *Didymo* proliferated show that the three species that increased in abundance with increasing chironomid densities had larger mouth gapes (*R. hyalinata*, *R. brunnea*, and *R. alberta*) (Figure 7). However, there was no relationship between *Rhyacophila* size and *Didymo* biomass at either scale, which rules out hypothesis 3 (associations with *Didymo* did not depend on *Rhyacophila* size).

Discussion

Results of our study provided evidence that the abundance of total *Rhyacophila* and some of the individual species increased at sites with greater proliferation of *Didymo*, while abundance of other species showed no relationship with the index of *Didymo* biomass. Those findings were not consistent with the hypothesis that *Rhyacophila* would avoid unfavorable habitat created by the thick *Didymo* mats. Alternatively, results were more consistent with the hypothesis that abundance of *Rhyacophila* may increase high *Didymo* locations because their preferred prey (Chironomidae) aggregated in those areas. In addition, results were not consistent with the third hypothesis, in that abundance of different *Rhyacophila* instars, which have increasing mouth gap sizes, had no relationship to the proliferation of *Didymo*. What we can take away from these observations is that availability of prey is the most important driver for the relationship between *Rhyacophila* abundance and *Didymo* biomass, regardless of the habitat. Below I elaborate on each of the major findings with comparisons to other studies.

If hypothesis 1 was correct, we expected *Rhyacophila* to avoid micro- and macrohabitats with high *Didymo*, because they are primitive, caseless caddisflies that need cold water with high dissolved oxygen. Higher dissolved oxygen is available at higher flows; and if flows decrease, then invertebrates may experience hypoxia (Prado and Garcia, 2016). *Didymo* mats have been shown to slow the flow near the surface of the substrate, thereby reducing dissolved oxygen and making it difficult for some invertebrates while favoring others (Larned et. al, 2011). This environmental condition may be a challenge for *Rhyacophila*, especially species who do not have gills, like *R. valuma*. *R. valuma* did not avoid *Didymo* but showed no tendency to aggregate in areas with *Didymo* blooms. In contrast, *R. alberta* with lots of gills showed the strongest tendency to aggregate in areas with *Didymo* blooms.

However, it may be difficult for *Rhyacophila* to forage in *Didymo* mats, even though prey are more abundant there. For example, chironomids show strong preferences for microhabitats and macrohabitats with *Didymo* blooms, possibly because they lead sedentary lives and use *Didymo* as a refuge from flow. In contrast *Baetis*' ability to eat epiphytic diatoms growing on the polysaccharide stalks of *Didymo* enables them to take advantage of this microhabitat, regardless of reductions in flow and dissolved oxygen. However, if *Baetis* chooses, it can drift to a place with less *Didymo* thanks to its mobility (Peckarsky, B. L., et. al, 1990), which may explain why *Didymo* does not affect its abundance (Brogan 2020).

We also observed changes in species phenology throughout the season, which may in part alter *Rhyacophila* their tendency to aggregate in *Didymo* patches where higher densities of prey are abundant. For example, the dominant species of chironomids changed from before (*Pagastia*) to after (*Rheotanytarsus*) *Didymo* bloomed, as did the species of *Baetis* from *bicaudatus* to *billybarrii*. Those species shifts may affect both the preference of *Rhyacophila* for *Didymo* and whether *Rhyacophila* aggregates at higher densities of prey. Other factors that change between before and after *Didymo* proliferated, like the flow goes down and the temperatures go up, which could affect how *Rhyacophila* responds to *Didymo* blooms that proliferated between the first and second set of samples. Finally, patterns of aggregation of *Rhyacophila* in areas of high prey density were much stronger before *Didymo* bloomed, possibly because after *Didymo* bloomed the tradeoff between foraging in areas of high prey and low oxygen weakened those patterns.

In addition, observations of different instars of *Rhyacophila* species that coexist in the same streams before and after *Didymo* bloomed provide further evidence that they may partition development time (Yang and Peckarsky, 2018). Of the two coexisting pairs of species, *R. hyalinata* develops earlier than *R. alberta*, and *R. valuma* develops earlier than *R. brunnea*. This observation may potentially explain how some *Rhyacophila* species avoid competing for resources. Evidence of this effect can be observed in the distribution of instars over the two collection times with *R. brunnea* and *R. alberta* being larger instars (3rd instars to pupae) in the second set of samples, while *R. hyalinata* and *R. valuma* were collected as 1st instars in the second set of samples, potentially because of a new generation hatched that will overwinter.

We also observed differences in the associations between *Rhyacophila*, their prey and *Didymo* blooms between the macrohabitat and microhabitat scales, which may be related to the interaction of flow, substrate, and the mobility of different species. Although *Didymo* may be continuous, covering full streams under low flow conditions, it can be very patchy when the flow is more heterogeneous, creating a patchwork of microhabitats where some are covered with *Didymo* and others are protected from scouring (Larned et. al, 2011). The cover of *Didymo* may be higher on stable substrates and lower in areas where the substrate is disturbed. *Rhyacophila* and *Baetis* are more mobile and able to move from patch to patch, which might reduce the effect of *Didymo* at the microhabitat scale. In contrast to the relatively sedentary chironomids, *Rhyacophila* and *Baetis* can move away from a habitat that has become inhabitable or low in food, or when *Didymo* becomes too difficult to navigate. However, some *Rhyacophila* species achieved higher densities in macrohabitats with more *Didymo* possibly because prey was more abundant at those sites, but they could take refuge in higher flow microhabitats within each site.

Finally, we had hypothesized that *Rhyacophila* with smaller mouth gapes may aggregate at sites or microhabitats with more *Didymo* if they prefer smaller prey, like chironomids, over larger prey, like *Baetis*, which does not aggregate in patches or streams with high *Didymo* proliferation. However, our results were not consistent with that hypothesis, possibly because preference for chironomids is not finely tied to mouth gape. At least three of the species (*R. alberta*, *R. brunnea* and *R. hyalinata*) aggregated in patches with more chironomids, suggesting that even individuals with larger mouth gapes prefer these prey (Thut, 1969), because they may be easier to catch than the more mobile *Baetis*. Little is known about the diet of these species, and we speculate that *R. valuma* (with the smallest mouth gapes) may not even be a predator. Previous experiments showed that the other three species consumed *Baetis* in small microcosms, but we have not yet tested predation by *R. valuma*.

All *Rhyacophila* species responded differently to *Didymo*, suggesting that the relatively weak relationship between *Didymo* and total *Rhyacophila* may be attributed to variation among these species. Some had no relationship, like *R. valuma*, while others like *R. hyalinata* and *R. brunnea* had weaker relationships. *R. alberta* showed a much stronger relationship. Such variation can dilute the overall effect of *Didymo* on *Rhyacophila* abundance. While all species of *Rhyacophila* have high oxygen demands, and prefer habitats with high flow (Ruiz 2019), the conflicting demands between foraging in locations with high prey density and foraging in unfavorable areas with lower dissolved oxygen would also weaken the overall effects of *Didymo* on *Rhyacophila*.

distributions. Conflicting demands are common for foragers who are trying to maximize intake of food but avoid risks of foraging in dangerous places (Sih 1980).

Conclusions and Implications

We conclude that at macrohabitat scale abundance of total *Rhyacophila* tended to be higher at sites with more biomass of *Didymo*, which runs counter to hypothesis 1, avoidance of bad habitat. All species prefer higher flows with more dissolved oxygen (Ruiz 2019). This result is more consistent with Hypothesis 2, predicting that *Rhyacophila* abundance is better explained by variation in food abundance. Also consistent with Hypothesis 2, chironomids were more abundant in samples and sites with more *Didymo* at both macrohabitat and microhabitat scales. Species showing the greatest response to *Didymo* blooms were ones that most strongly aggregated in samples with more chironomids (*R. alberta*). Finally, conflicting demands (food vs habitat), may weaken the relationship between *Didymo* and total *Rhyacophila*. While the habitat is not favorable, the higher amounts of prey may be enough to override the negative effects of foraging in a bad habitat.

Our study has several implications related to climate change. Earlier snowmelt and lower snowpack cause lower stream flows in these oligotrophic streams that make them favorable for *Didymo* to proliferate (Taylor and Bothwell, 2014). Perhaps future research should focus on dissolved oxygen at the microhabitat scale in these streams, and its potential effects on invertebrates during these lower streamflow years that would not only cause a shift in communities, and lower quality food for trout in these streams (Prado and Garcia 2016, Taylor unpublished data), but also could cause extinction of species requiring high dissolved oxygen. Communities of stream insects are shifting from mayflies to chironomids and oligochaetes (Brogan 2020), which has implications not only for invertebrate predators like *Rhyacophila*, but also for trout who showed reduced growth rates in streams with *Didymo* blooms compared to those without *Didymo* (James et. al. 2010, Taylor, B. W, unpublished data). While some *Rhyacophila* species may benefit from increases in prey density associated with *Didymo* blooms, extreme consequences of climate change could be detrimental if there is not enough water in the streams during dryer years to sustain their populations.

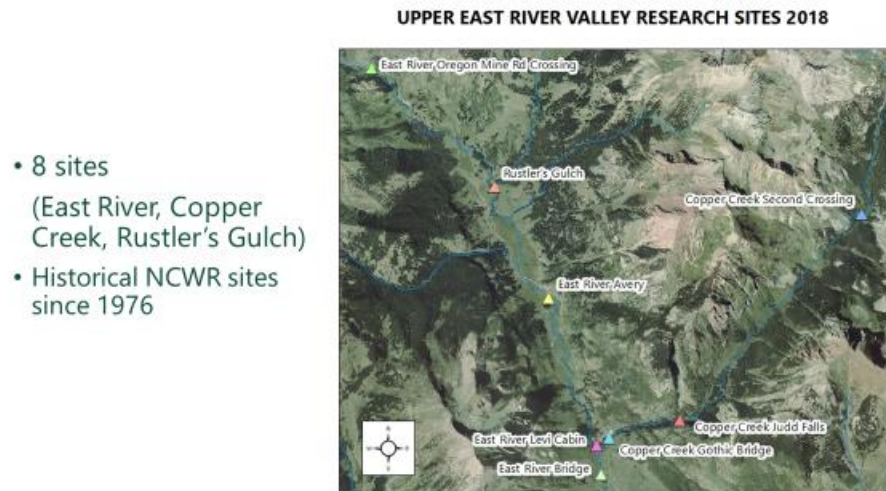


Figure 1. Sites used in this study. A part of the long-term data set. Map created by JaHyun Yang.

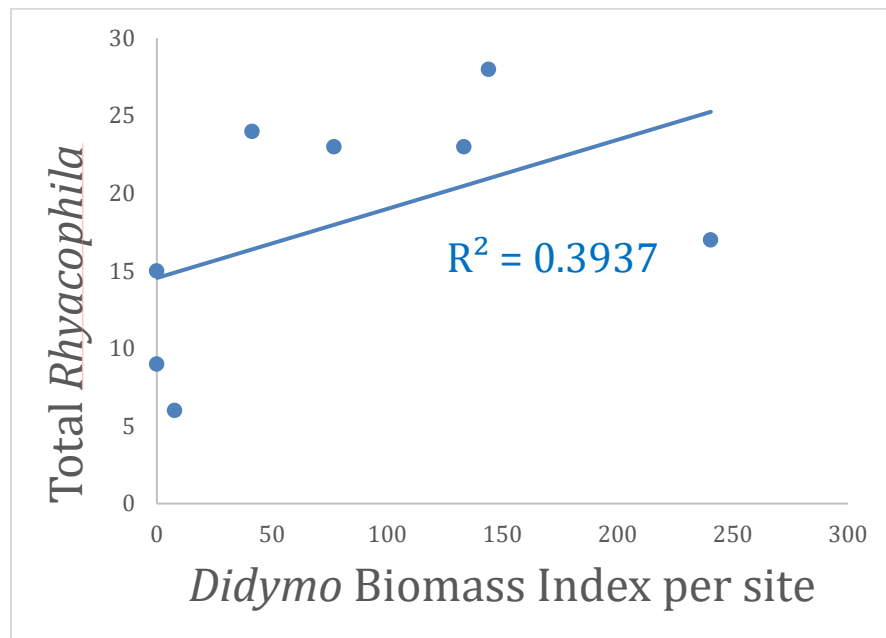
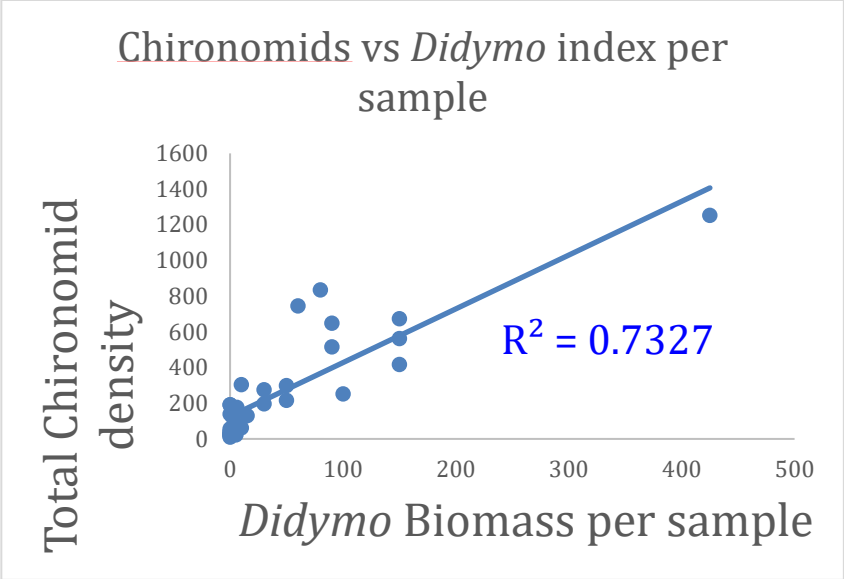


Figure 2a. Total *Rhyacophila* vs *Didymo* biomass per site.



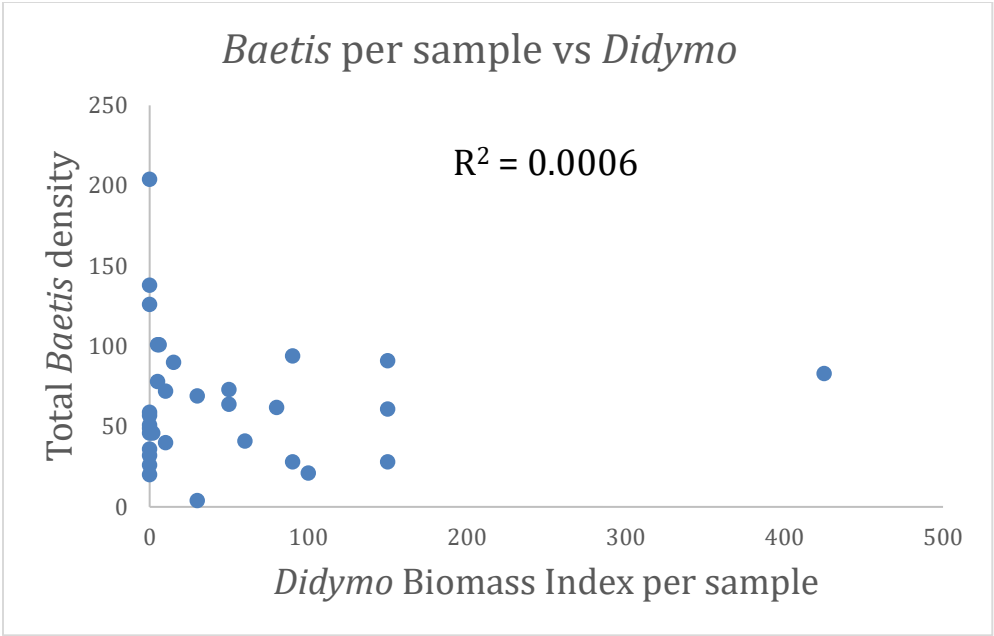


Figure 3c. Total *Baetis* vs *Didymo* biomass per sample.

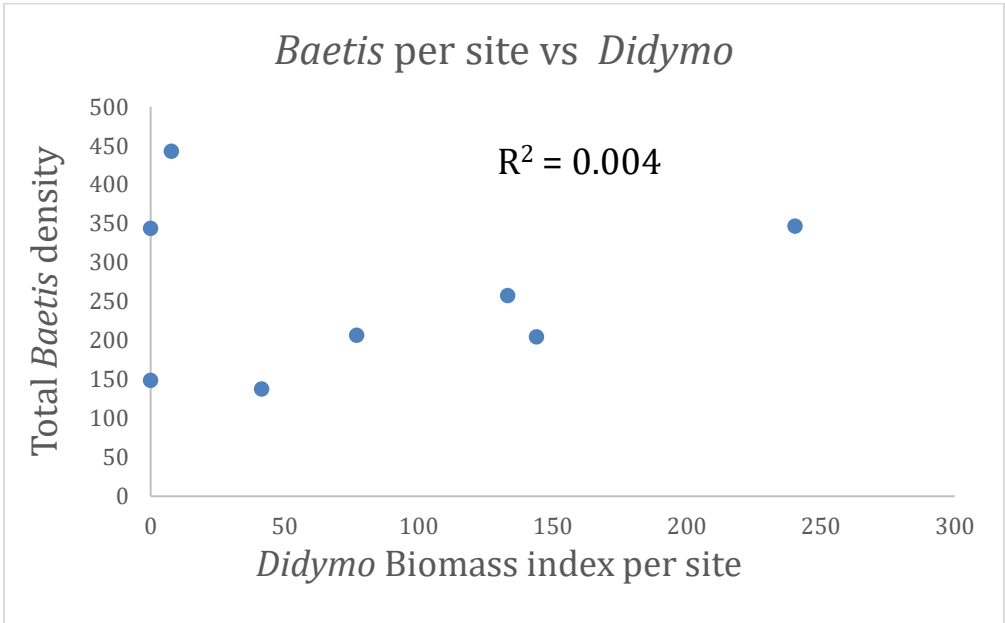


Figure 3d. Total *Baetis* vs *Didymo* per site.

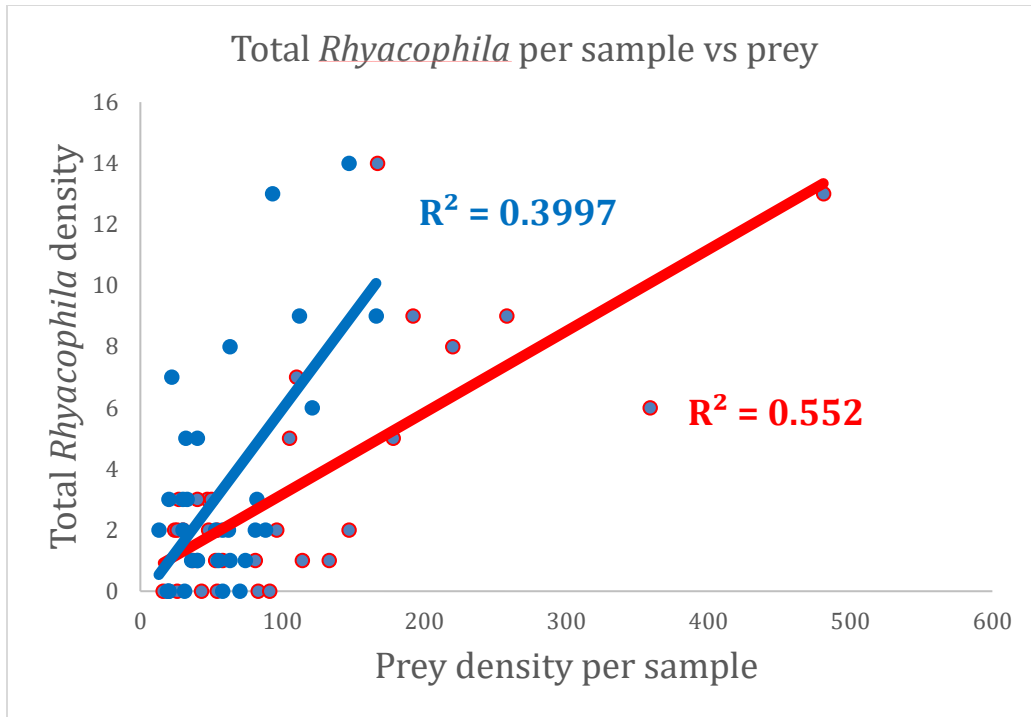


Figure 4a. Total *Rhyacophila* per sample vs *Baetis* (blue) and chironomid (red) density.

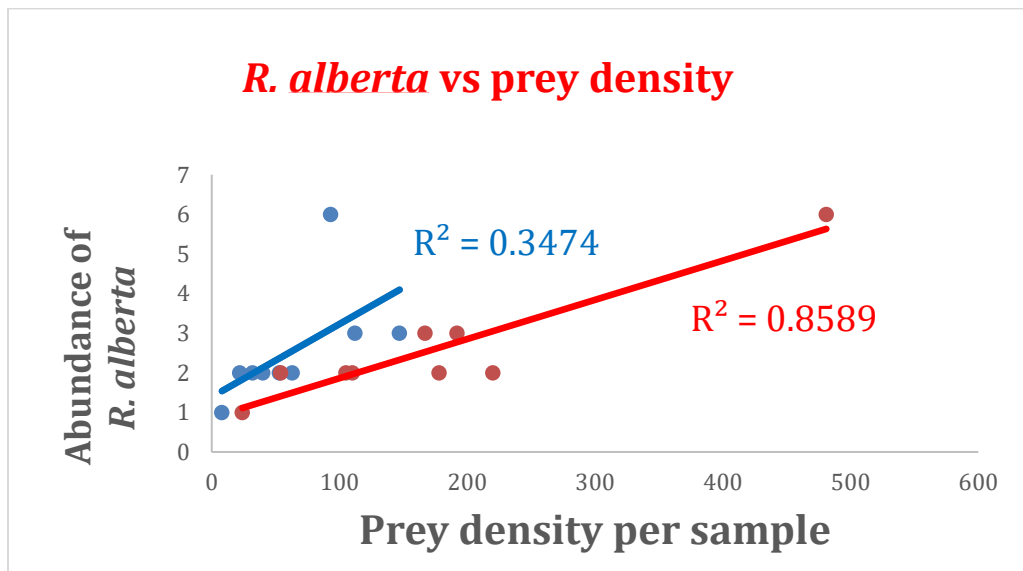


Figure 4b. *Rhyacophila alberta* vs prey density per sample vs. *Baetis* (blue) and chironomid (red) density

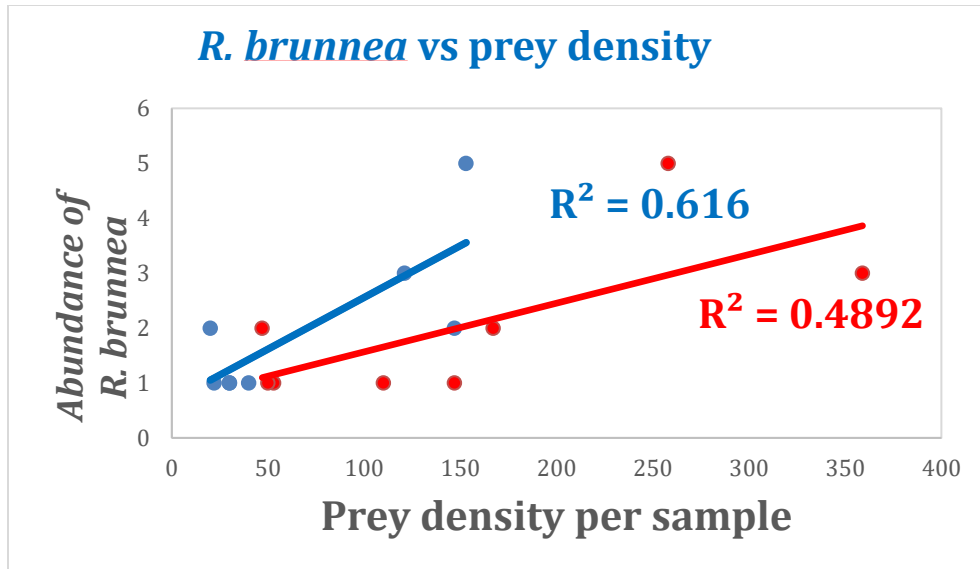


Figure 4c. *Rhyacophila brunnea* vs prey density per sample vs. *Baetis* (blue) and chironomid (red) density.

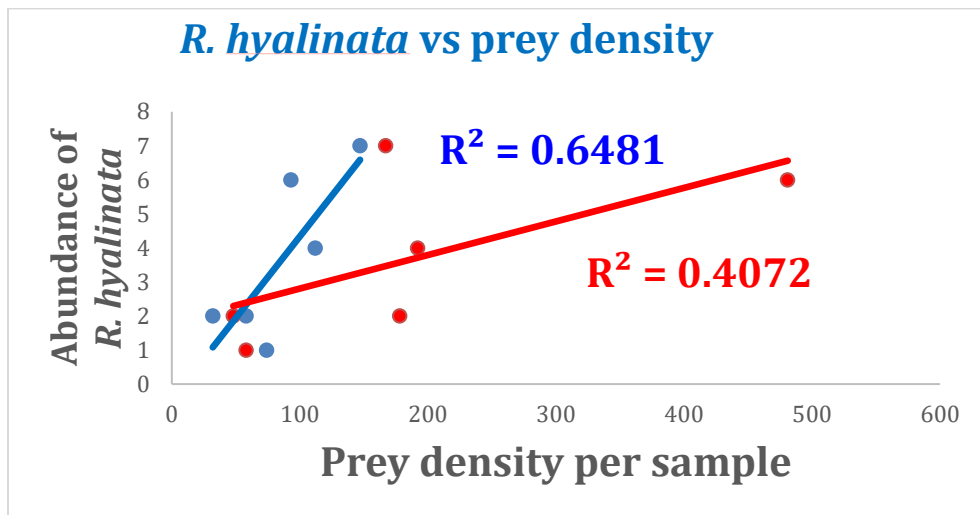


Figure 4d. *Rhyacophila hyalinata* vs prey density per sample vs. *Baetis* (blue) and chironomid (red) density

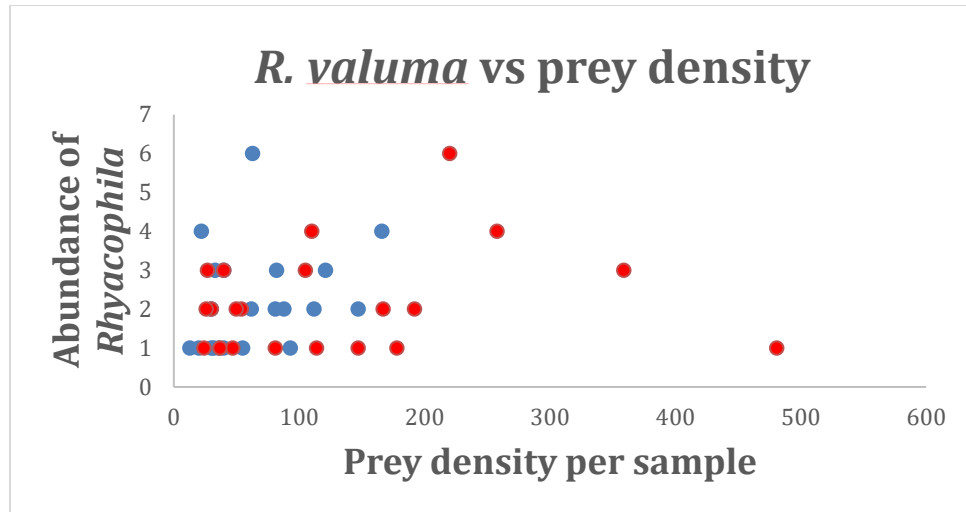


Figure 4e. – *Rhyacophila valuma* vs prey density per sample vs. *Baetis* (blue) and chironomid (red) density

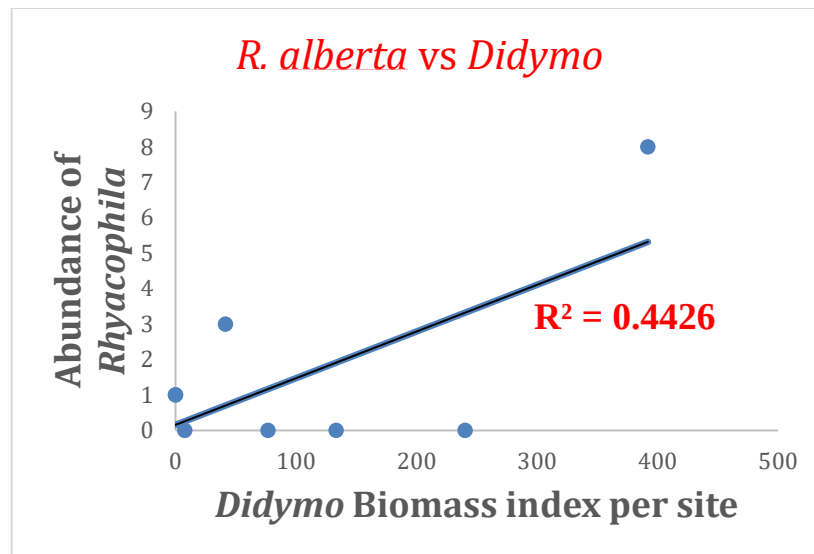


Figure 5a – *Rhyacophila alberta* abundance vs *Didymo* biomass per site.

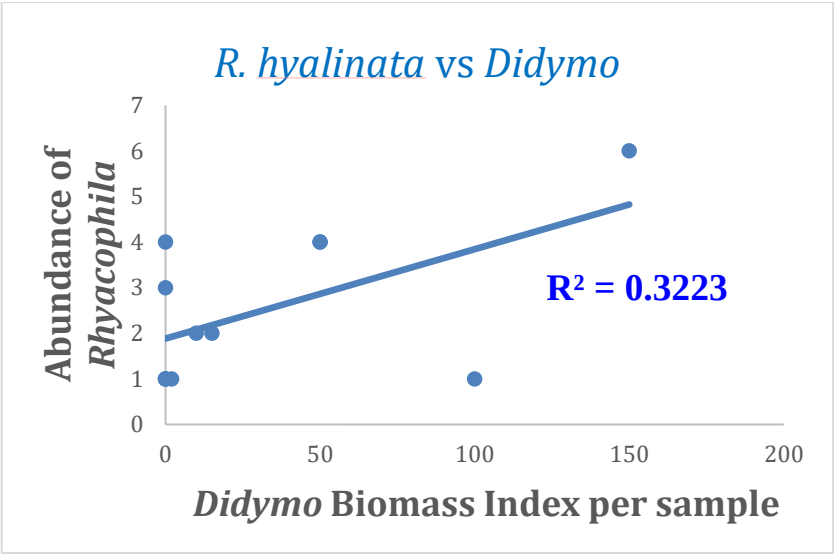


Figure 5b – *Rhyacophila hyalinata* abundance vs *Didymo* biomass per sample.

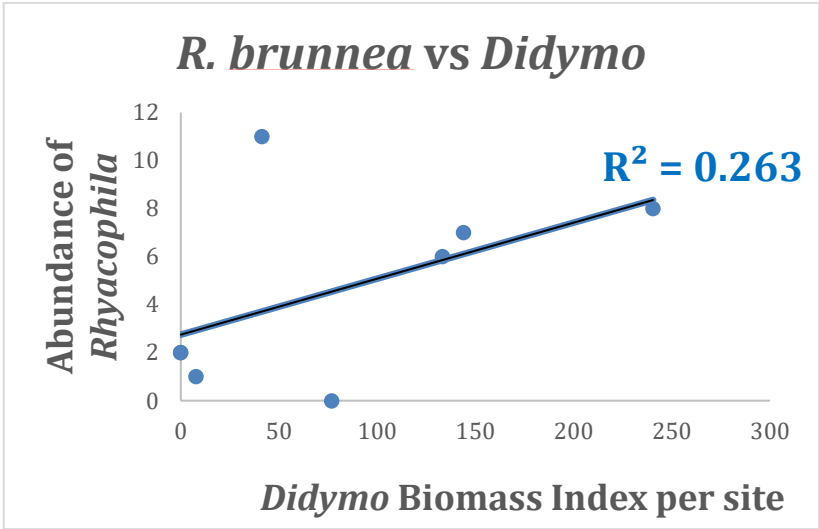


Figure 5c - *Rhyacophila brunnea* vs *Didymo* biomass per site.

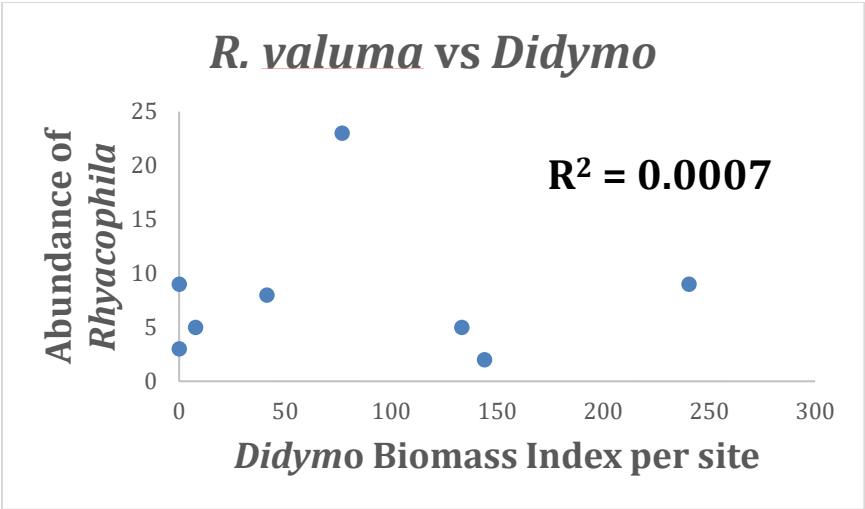


Figure 5d – *Rhyacophila valuma* abundance vs *Didymo* biomass per site.

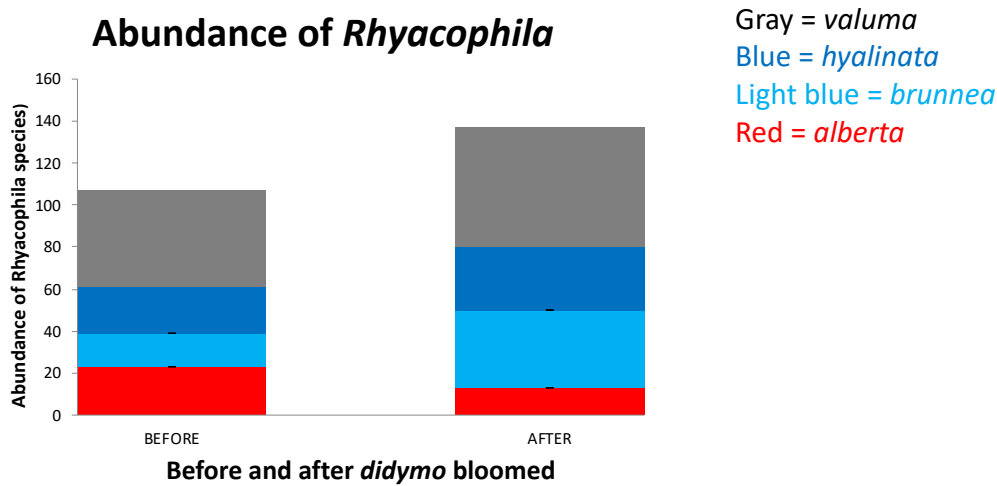


Figure 6 – Relative abundance of the four common species of *Rhyacophila* before and after *Didymo* proliferated.

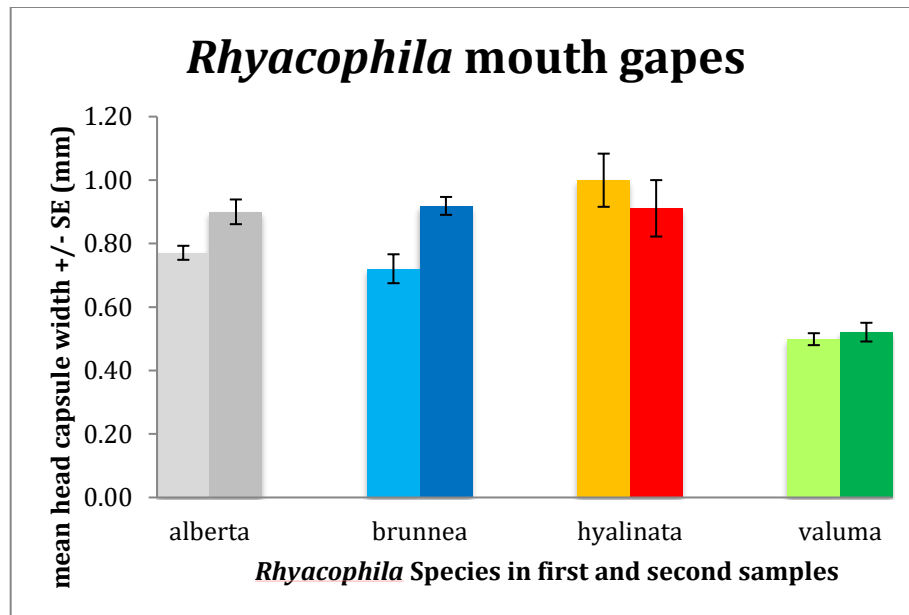


Figure 7 - Mean sizes (mouth gapes) +/- 2 standard errors of the four most common species of *Rhyacophila* before (left) and after (right) *Didymo* proliferated.

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