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Will Populations of Macroinvertebrate Functional Feeding Groups Survive Precipitation Changes?

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Background

Climate change is a pervasive issue that has the potential to have detrimental effects on many freshwater organisms and their habitats. Fluctuations in precipitation, changes in temperature, and other long-term shifts in weather patterns are just a few examples of the ways in which climate change is impacting the world around us (“What is Climate Change?” n.d.). The Mill River in Northampton, Massachusetts is an ideal location to measure some of these impacts on macroinvertebrates in various functional feeding groups. Macroinvertebrates are small organisms that lack an internal skeletal system, and their functional feeding groups refer to “the type of food resource that a particular species utilizes” (Stumpf et al. 2009.). A study by Kim et al. (2017) studied the effects of rainfall intensity on macroinvertebrates in a mountain stream in Korea, where summer monsoons occur frequently. After collecting data for three days, it was found that the rainfall’s intensity (more than frequency) affected the species richness and abundance of the macroinvertebrates inhabiting the stream (Kim et al. 2017). Their existence is essential in being able to understand the ecology of aquatic ecosystems, so understanding how precipitation impacts their population size is important in beginning to understand the effect of climate change on these spaces (Hauer and Resh 2017). In our study, we will specifically explore the question, “How does precipitation affect the abundance of different functional feeding groups in Mill River?”

Hypothesis and Predictions

The three main functional feeding groups found in the Mill River are collector gatherers, scrapers, and filter-feeders (M.C. Pratt personal communication). Within these three groups respectively, large populations of midges, limpets, and net-spinning caddisflies call Mill River their home.

Scrapers - Limpets

Limpets (Ancylidae) are scrapers and use their tongues to scrape the surface of rocks for sustenance (American, 2022). They have strong foot muscles that attach their shell to rocks to support anchoring in more rough environments. Climate change can impact precipitation levels each year, and increased precipitation levels likely result in an increase in water flow. This makes the strong foot of the limpet an asset to their survival by helping them stay attached to the rock by which they are sustained. There has not been extensive research specifically on freshwater limpets' response to precipitation. However, a study conducted on marine limpets by Denny and Blanchett (2000) found that faster water flow does not typically result in limpets dislodging from the rocks.

It is important to note that there are differences in body plan and population dynamics between marine limpets and the freshwater limpets that we analyzed. In particular, a study by Vermeij (2016) found that while there is not extensive data on limpet evolution, there was a gradual transition from gastropods with spiral shells to modern limpets with "slipper-shaped" shells and strong feet, and this evolution occurred multiple times independently (Vermeij, 2016). The evolution to this body plan, especially the strong foot, is likely advantageous to stay put in fast-flowing water conditions such as freshwater rivers (M.C. Pratt personal communication). We hypothesized that an increased level of precipitation in the Mill River would not impact the density of limpets because they have evolved a strong foot to attach themselves to the rocks and may be able to withstand faster water flow that results from higher precipitation. Thus, we predicted that the number of limpets per square meters would not be larger or smaller as precipitation levels fluctuate.

Collector-Gatherers - Midges

While freshwater midges (Chironomidae) do not typically scrape rock surfaces for food, they are primarily collector-gatherers and feed on small pieces of organic matter that is sometimes lodged in between rocks. (Maine Department of Environmental Protection [Accessed 2023 Mar 9]). According to a study by Porinchu and MacDonald (2003), midges are tolerant to changes in salinity, but sensitivity to temperature and dissolved oxygen vary with species (Porinchu and MacDonald, 2003). This study also noted that collector-gatherer macroinvertebrates attach their eggs to small pieces of sediment and then locate organic matter for food (Porinchu and MacDonald, 2003). Waldvogel et al. (2018) noted that the majority of midges' lives are spent as larvae, during which they eat various types of "organic debris" along the bottom of the water (Waldvogel et al., 2018).

The fall is the only time of year during which midges do not actively develop; instead, they remain "mature larvae" and move through the water until they create pupae in the spring (Waldvogel et al., 2018). This means that the majority of midges in the Mill River were likely in the larval stage in the data that we analyzed (Fall 2019-2022). We hypothesized that the density of midges in the Mill River would decrease as precipitation levels increased because the faster water flow from higher precipitation may cause pieces of sediment to be swept away, preventing midges from finding food or shelter to which they would attach their eggs (Porinchu and MacDonald, 2003). In addition, we hypothesized that midge density would decrease because dissolved oxygen levels and water temperature typically fluctuate as precipitation levels change (Marcy et al., 2022), to which midges are sensitive (Porinchu and MacDonald, 2003). Thus, we predicted that the number of midges per square meters would decrease as the level of precipitation increases.

Filter-Feeders - Net-Spinning Caddisflies

Net-spinning caddisflies (Hydropsychidae) are filter-feeders and are known for their ability to produce silk threads and spin them into elaborated nets. The nets act as filters: filtering out water to catch food (Life in Freshwater [Accessed 2023 May 9]). Net sizes vary among species of caddisflies, since sizes are based on food needed and water current speeds (Life in Freshwater [Accessed 2023 May 9]). Yet, their food generally consists of tiny bits of organic debris, and, sometimes, small organisms (Macroinvertebrates.org [Accessed 2023 May 9]). Although there's a misconception that *all* Net-spinning caddisflies are tolerant to pollution, it is true that they are sensitive to changes in the environment such as water temperatures and river runoff and flow. Most Net-spinning caddisflies require a moderate running water stream to better capture food (Macroinvertebrates.org [Accessed 2023 May 9]). Since net-spinning caddisflies tolerate low oxygen concentrations, however, an increase in dissolved oxygen and decrease in temperature from higher precipitation levels (Marcy et al., 2022) can create an unsuitable habitat for net-spinning caddisflies (EcoSpark [Accessed 2023 May 9]).

We hypothesized that the density of net-spinning caddisflies in the Mill River would increase as precipitation levels increased because more food is delivered to their habitats with faster water flow caused by heavier precipitation. However, we also hypothesized that if the flow increased to the point where it was too strong and could break the nets, the population of net-spinning caddisflies would decrease or would be displaced as a result of fast water currents. Thus, we predicted that the density of net-spinning caddisflies in the Mill River would first increase as precipitation levels increased, but then would cross a threshold and decrease as precipitation levels continued to increase.

Data Used

We used data gathered from Dr. Marney Pratt's fall labs from the years 2019 through 2022 (Pratt, 2022a). Collection sites were located both upstream and downstream of Paradise Pond—an artificially constructed body of water on the Smith College Campus located in the Mill River in Northampton, MA. Within the upstream and downstream locations, data was collected from five different microhabitats, however in our research we chose to not distinguish between these, and instead distinguished only the broader locations of upstream and downstream. The total area sampled downstream from 2019-2022 was 22.75 meters squared (m^2) with a total of 60 samples (see Table 1). In contrast, the total area sampled upstream over all the years was 24.50 m^2 with a total of 55 samples taken. A single sample is defined as one whole microhabitat sampled on the same date. The data were analyzed using density calculations of each functional feeding group that were present in both locations. Density was calculated by having the number of a specific functional feeding group (scrapers, collector-gathers, or filter-feeders) be divided by the area sampled.

Table 1: Summary table for sampling efforts upstream and downstream of Paradise Pond in the Mill River, from Fall 2019 to Fall 2022. Each sample contains data from one microhabitat collected on a single day.

Season	Location	Dates	# of Samples	Total Area Sampled (m^2)
Fall	Downstream	2019-09-17, 2019-09-23, 2019-09-26, 2020-09-18, 2020-09-20, 2020-09-26, 2021-09-23, 2021-09-28, 2021-09-29, 2022-09-22, 2022-09-28, 2022-10-03	60	22.75
	Upstream	2019-09-16, 2019-09-24, 2019-10-03, 2020-09-19, 2020-09-25, 2020-09-27, 2021-09-22, 2021-09-30, 2022-09-21, 2022-09-27, 2022-09-29	55	24.50

Results

Limpets

There is no clear correlation between limpet density and amount of precipitation at the upstream location of the Mill River (Figure 1). However, as precipitation increases downstream, it is observed that limpet density also experiences a slight increase (Figure 1). It is also important to note that the collection density of limpets was quite small, with the maximum downstream density being 104 limpets per square meter, and upstream density reaching only 92 limpets per square meter (Table 2).

Table 2: Descriptive statistics of limpet density in number per meter squared.

location	median	IQR	min	max	N
Downstream	1	10	0	104	60
Upstream	8	18	0	92	55

IQR = interquartile range, min = minimum, max = maximum, N = number of samples

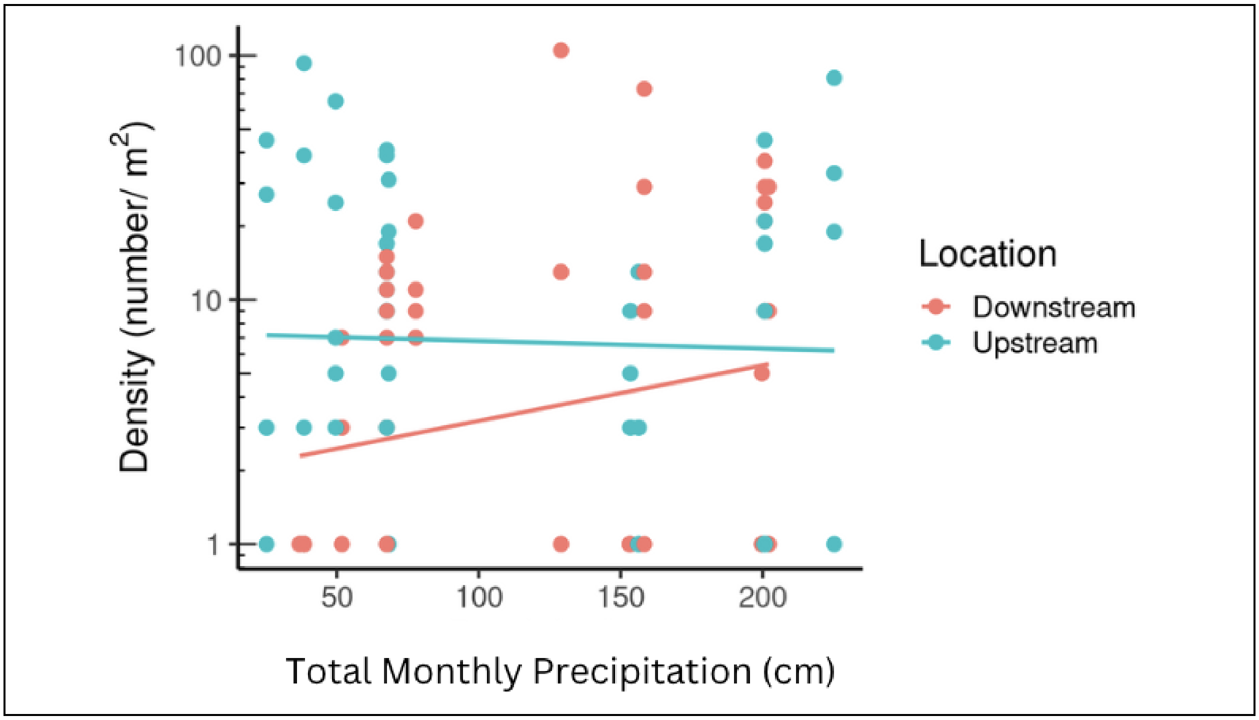

Figure 1: Relationship between limpet density (number per meter squared) and total monthly precipitation (in centimeters) for both upstream and downstream locations of Paradise Pond in Mill River (Northampton, MA). Each dot represents the density of limpets in a sample taken from a microhabitat on the same day (M.C. Pratt personal communication). The y-axis is presented on a logarithmic scale, which means that the data from each year can be directly compared to one another without further calculations, despite annual changes. The blue and red lines represent the lines of best fit for upstream and downstream data respectively.

Midges

Similarly to the results to limpets, there was no clear correlation between precipitation levels and midge density downstream of Paradise Pond. However, there was a slightly positive relationship upstream (Figure 2). Though the downstream data showed neither a positive nor negative relationship, the median was notably higher downstream than upstream (Table 3). The median midge density downstream of Paradise Pond was 58, whereas it was only 30 upstream. However, the maximum upstream density was 782 midges per square meter, but only 764 midges per square meter downstream (Table 3), showing the slight increase in upstream density as precipitation increases. There is also a noticeable gap in midge density in both locations between ~75 and ~150 cm of precipitation, causing a negative slope in the curve. However, there is another increase in both locations after ~150 cm of precipitation (Figure 2).

Table 3: Descriptive statistics of midge density in number per meter squared.

location	median	IQR	min	max	N
Downstream	58	176	0	764	60
Upstream	30	92	0	782	55

IQR = interquartile range, min = minimum, max = maximum, N = number of samples

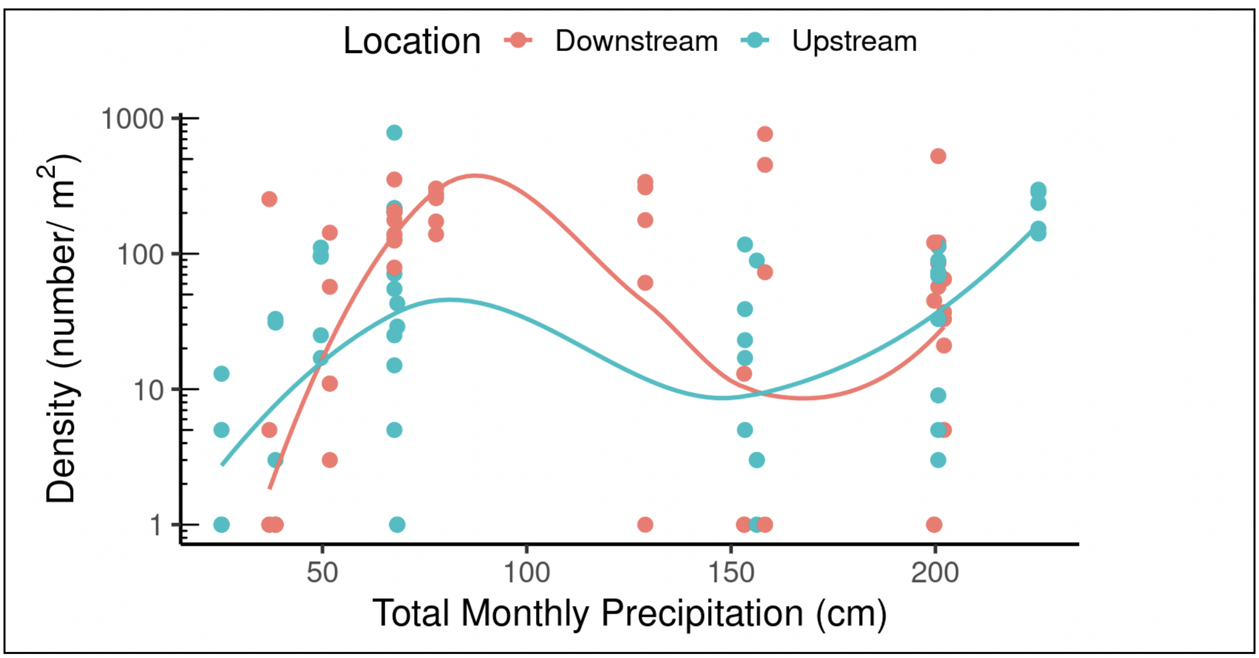

Figure 2: Relationship between midge density (number per meter squared) and total monthly precipitation (in centimeters) for both upstream and downstream locations of Paradise Pond in Mill River (Northampton, MA). Each dot represents the density of midges in a sample taken within a microhabitat on the same day. The y-axis is

presented on a logarithmic scale, which means that the data from each year can be directly compared to one another without further calculations, despite annual changes. The blue and red curves represent best fit for upstream and downstream data respectively.

Net-Spinning Caddisflies

There is a relatively positive relationship between the density of net-spinning caddisflies and amount of precipitation downstream of Paradise Pond in the Mill River (Figure 3). On the other hand, there is a slight negative correlation between the same two variables upstream (Figure 3). However, overall, there were more net-spinning caddisflies and a greater rate of precipitation downstream than upstream (Figure 3). For example: while downstream has a maximum density of 3, 304, upstream has a maximum density of only 192 (Table 4).

Table 4: Descriptive statistics of net-spinning caddisfly density in number per meter squared.

location	median	IQR	min	max	N
Downstream	177	415	4	3,304	60
Upstream	18	32	0	192	55

a) IQR = interquartile range, b) min = minimum, c) max = maximum, d) N = number of samples

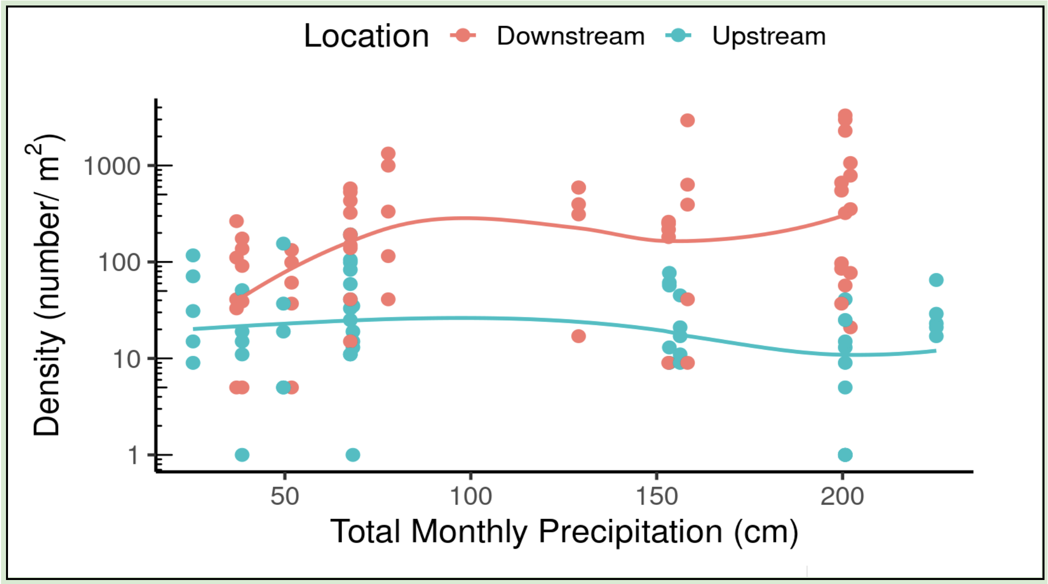

Figure 3: Relationship between net-spinning caddisfly density and total monthly precipitation (in centimeters) for both upstream and downstream locations of Paradise Pond in Mill River (Northampton, MA). Each dot represents the density of net-spinning caddisflies in a sample taken within a microhabitat on the same day. The y-axis is presented on a logarithmic scale, which means that the data from each year can be directly compared to one another without further calculations, despite annual changes. The blue and red lines represent the lines of best fit for upstream and downstream data respectively.

Interpretation of Results

For collector-gatherer midges and filter-feeder net-spinning caddisflies, we predicted that there would be a decrease in their densities as increased precipitation caused an increase in dissolved oxygen and a decrease in temperature. Although density decreased for midges and net-spinning caddisflies during certain precipitation levels, we found that the specific locations as to where density decreased varied. In addition, both midge and net-spinning caddisfly density actually increased at the lower and higher ranges of precipitation while showing a more negative relationship in the middle ranges. This conflicted with our hypothesis that net-spinning caddisflies would thrive in medium levels of precipitation but be displaced in higher levels. While the upstream and downstream curves had similar shapes on each graph, the midges and net-spinning caddisflies downstream certainly preferred lower precipitation levels (~50-100 cm) more than those upstream (Figure 2, Figure 3). One possible explanation for this phenomenon can be the different preferences in environmental temperatures. Although the two blanket locations where the data were collected exist less than a mile apart from each other, changes in temperature based on tree canopy, river depth, and a variety of other factors can have a noticeable effect on the temperature of an area even a couple of feet away from each other (Kail et al. 2021). This has the potential to impact macroinvertebrate populations, as discovered in a study by Durance and Ormerod (2007), where they found that macroinvertebrate abundance could decline by 21% for every 1°C rise in temperature (Durance and Ormerod, 2007).

In contrast to the collector-gatherers and filter-feeders, our predictions that scraper limpets would not be impacted as much by precipitation was mostly supported by the results, however there was more variation and less of a predictable trend than we had anticipated seeing. There were several fluctuations in our results even during months with equal total monthly precipitation levels, so we could not identify a consistent reason for these changes in density with the factors that we were focusing on. Further research with a bigger sample size could be useful to see if the density increase that is beginning to show up in the downstream data continues to grow as precipitation increases, but as of right now we do not have enough information to see if this is a noteworthy correlation.

The results partially supported our hypothesis in regards to collector-gatherers. Midges prefer to be in warmer temperatures (Waldvogel et al., 2018), so it would be expected that midge density would be greater downstream of Paradise Pond where the temperature tends to be a little warmer. This was in fact the case, however we did not hypothesize a difference in density upstream and downstream, only a difference in relation to precipitation levels. This provides the context that the higher density of midges downstream may actually be due to warmer temperatures downstream rather than a result of precipitation fluctuations. Increased precipitation decreases water temperature (Rooney et al., 2018), meaning the river may become a less suitable habitat for midges and cause a decrease in density, especially upstream. In this case, the results would support our hypothesis, and would align with the study by Porinchu and MacDonald (2003) where freshwater midges were sensitive to temperature depending on species. However, for the scope of this research, we did consult the data regarding water temperatures during Fall 2019-2022 or the specific species of midges, meaning we could not determine whether this was the case.

Conclusion

A multitude of further research is necessary to determine whether an increase in precipitation in the Mill River has a clear effect on the density of collector-gatherer and filter-feeder macroinvertebrates. Our research did not take into account the difference in density between upstream and downstream of Paradise Pond; it is likely that the density of midges and net-spinning caddisflies differs upstream and downstream regardless of precipitation fluctuations based on the fact that there was a higher density downstream. Finally, our research does not account for biotic interactions of any of the three functional feeding groups; it does not include any changes in competition between macroinvertebrate species or predator density. Research on these factors during the fall seasons from 2019-2022 would supplement our research. Furthermore, our findings could provide a basis for future studies on how precipitation levels in the Mill River impact the density of predators both upstream and downstream.

It is incredibly important to observe and record how environmental factors such as precipitation affects population dynamics of macroinvertebrates. While there may not be a substantial decrease in all functional feeding groups in the past four years, climate change could cause this to be different in the future. Both an increase in flooding or drought conditions in the region during the next several years may require macroinvertebrate density to be more intensely monitored, or affect the ratio of prey and predators of these three functional feeding groups. Thus, our research can provide a baseline for the levels of precipitation and density of scrapers, collector-gatherers, and filter-feeders in the Mill River.

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