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How Flow Regime Affects Predator-Prey Relationships of Stream Darter and Shiner Species

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How Flow Regime Affects Predator-Prey Relationships in Stream Darter and Shiner Species

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Abstract

Analysis of the interactions between abiotic and biotic factors of environments and ecosystems is a highly valued area of research. This study focuses on the interactions between the biotic component of predation and foraging of certain stream fish species and the abiotic component of the flow regime that those species reside in. Gut content analysis followed by statistical calculations in the form of t-tests and chi -quared tests were performed on two fish species who both inhabited a stream with a groundwater flashy flow regime as well as a stream with a runoff flashy flow regime. The research showed that some predatory outcomes, such as the types of food consumed by the fish species, were different between the different flow regimes. Other predatory outcomes, such as how much food in terms of weight was consumed, were not different between the different flow regimes. This is important because it shows how flow regime can be more influential on one area of predator-prey relationships than others, even if those two areas are closely related. Thus, the way that abiotic and biotic factors influence each other can be very specific.

Introduction

Biotic processes such as predation and foraging are not without influence from abiotic factors. Biotic factors include the living things within an ecosystem, such as plants, animals, and bacteria. Abiotic factors include the nonliving things within an ecosystem, such as temperature, atmosphere, water, and soil. Abiotic factors can have important influences on organisms and ecosystem function (Dunsen and Travis, 1991). In a study performed by Franco and Budy (2005), competitors (a biotic factor) and temperature (an abiotic factor) were observed to analyze the influence they had on one another, and how that influence affected conditions of salmonid fishes along a longitudinal gradient in a mountain stream. Conclusions of this study reveal that cutthroat trout dominated the fish community in mainstream reaches with the lowest average minimum temperatures and the highest diel temperature fluctuations, while brown trout dominated warmer reaches with less diel fluctuations (Franco and Budy, 2005). It was further determined that, because cutthroat and brown trout selected different prey types despite the similar invertebrate composition in the transitional zone, some combination of factors (such as the temperature conditions) causes cutthroat trout to alter their feeding behavior (Franco and Budy, 2005). This summary of the research done serves to illuminate one example of how biotic and abiotic factors interact with and influence one another.

Flow regime, essentially a description of a river’s pattern of flow structure (including timing, quantity, and variability), is an abiotic factor that plays a pivotal role as a key driver of the ecology of rivers and streams. According to Leasure, Magoulick, and Longing (2016), flow regimes of stream and river ecological communities represent the natural hydrologic conditions to which the aquatic organisms that live in it are best adapted. It is a major determinant of physical habitat and biotic composition in streams, it can drive evolutionary life history strategies of aquatic species, and it affects river/stream longitudinal and lateral connectivity, which is essential to the viability of populations of many species (Bunn and Arthington, 2002). In the Ozark-Ouachita Interior Highlands region of Arkansas, Missouri, and Oklahoma, there are seven natural flow regimes identified; these regimes are groundwater stable, groundwater, groundwater flashy, perennial runoff, runoff flashy, intermittent runoff, and intermittent flashy (Leasure et al., 2016).

Within riverine systems, hydrology/flow is often the primary abiotic variable that determines the physical habitat available and provides the template upon which biotic interactions including predation and competition occur (Turschwell et. al, 2019). One of the primary biotic factors that flow regime will influence are the fish species that occupy that flow regime. Flow regime as an abiotic construct will not only be interconnected with the biotic species, but also the biotic processes that make up the nature of those fish species (such as their means of foraging and predation). Because runoff flashy streams tend to have more variability than groundwater flashy streams, they would have greater abiotic environment-fish relationships than groundwater flashy streams (Magoulick et. al, 2021). It is reasonable to suggest that when there is greater variation in an abiotic component of an ecosystem, there will be a more complex system of biotic interactions with that abiotic component. Further, with foraging being a biotic process that is affected by flow regime, more variabilities in a flow regime would suggest more complexities in foraging methods within that flow regime. Hydrologically variable streams are characterized by species with generalized feeding strategies and preference for low water velocity, silt, and general substrata; but, in more stable streams, fish assemblages contain more silt-intolerant trophic specialists (Poff and Allan, 1995).

Another factor to be considered is the energetic cost of capturing different prey species found in more or less variable environments. Fish are expected to feed in the way that costs less energy for them and/or allows them to gain the most energy from their food source (Elliot and Hurley, 2001). For instance, predators act not by choosing foods proportional to their abundance, but selectively prey on specific organisms or even particular life stages of organisms in order to maximize energy gain (Stein, 1977). Stein (1977) provided evidence for this in his research of the smallmouth bass prey selectivity on various sizes and life stages within crayfish. He concluded that, because small size classes of large substrates are relatively less exposed than large size classes (and increased waiting time to obtain those small size classes decreased their value), more available intermediate size classes were sought out instead (Stein, 1977). Regarding how the concept of energetic cost and gain applies to this study, it could be that differences in the characteristics of flow regimes cause one method of foraging for a specific species to be energetically favorable in one flow regime, but energy costing in another. To highlight the work of David P. Gillette (2012), it is reasonable to suggest that selection for various prey types will differ among riffles (riffles are the shallower, faster moving parts of a river, and different flow regimes will be characterized by different amounts/types of riffles present in them), and that relative profitability of prey items varies among riffles as a consequence of abiotic variation. This further expands on the idea that variability in an abiotic factor causes greater complexity in biotic processes, such as foraging. An example of this construct can be reflected in the work of Gotceitas and Colgan (1989), who concluded that increasing habitat complexity significantly reduced the foraging success of largemouth bass feeding on juvenile bluegill sunfish.

In order to investigate how the differences in flow regime affect the foraging and predator-prey relationships of fish species, I chose to look at two species of fish that would be found in both groundwater flashy streams and runoff flashy streams. I would then be able to analyze their gut contents and examine effects of flow regimes on foraging. The two species I examined were the orangethroat darter and the duskystripe shiner.

The orangethroat darter (*Etheostoma spectabile*) is very commonly found in the Ozarks. They live in slow-moving riffles in streams, and they mostly hold closely to the bottom of streams. In small streams, they generally remain in the same location, especially between riffles (Gillette, 2012). Examples of their diet include midge larvae and sowbugs, and their means of foraging includes using head and eye movements for prey location and making persistent short movements across stream bottoms. In a study performed by Vogt and Coon (1990) where they compared the foraging behavior of rainbow darters and orangethroat darters, chironomid larvae were a primary dietary component. Their work also revealed that both species moved greater distances and made more body moves and turns (behaviors intended towards predation) in pools than in riffles, and the orangethroat darter attempted more strikes in pools than in riffles (Vogt and Coon, 1990). This occurred despite the fact that prey are less abundant in pools and are distributed in a less clumped pattern than in riffles. This provides further evidence that abiotic conditions of flow, this particular case showing the flow difference in pools vs. riffles, affect biotic processes such as foraging and predation.

The duskystripe shiner (*Luxilus pilsbryi*) are also commonly found in Ozark streams. More specifically, they are found in headwater streams. Adults occur in riffles of clear, small to moderately large streams with a clean gravel substrate and strong continuous flow as well as moderately deep pools with noticeable current (Mayden, 1988). Fishes in the genus *Luxilus* generally consume aquatic invertebrates as well as terrestrial invertebrates and plant material (Alexander and Perkin, 2013). Duskystripe shiners lean more towards the invertebrate side of the prey spectrum, though they do eat algae.

While there are many different abiotic factors that affect many different biotic processes, the focus of this research is to determine how flow regime, an abiotic factor, plays a role in the predator-prey relationships of both the orangethroat darter and the duskystripe shiner. Each of these species was collected and analyzed from streams of two different flow regimes: groundwater flashy and runoff flashy. My question explores whether the differences in the flow regimes affect predation by the two species. My hypothesis not only suggests that there is a significant difference in predatory activity/foraging caused by differences in flow regime type, but it also reflects the findings of Gotceitas and Colgan previously described: that the foraging activities of orangethroat darters and duskystripe shiners in the more variable runoff flashy streams will be less successful than that of those in the more stable groundwater flashy streams. I hypothesize that an environment that supports more stability and constancy will provide better means for success (success being defined as a greater amount of food consumed by weight as well as more types of insect prey consumed) in foraging and predatory activities.

Methods

There were four study groups in total: orangethroat darters from Mikes Creek, duskystripe shiners from Mikes Creek, orangethroat darters from Lollars Creek, and duskystripe shiners from Lollars Creek.

Table 1. Summary of Subjects Used

Location	Species	Date Caught	Amount Caught
Lollars Creek	Orangethroat Darter	6/20/19	9
Lollars Creek	Duskystripe Shiner	6/20/19	20
Mikes Creek	Orangethroat Darter	7/26/19	15
Mikes Creek	Duskystripe Shiner	7/30/19	10

Study Sites

Groundwater flashy and runoff flashy are the two flow regimes that are analyzed in this study. Mikes Creek is the groundwater flashy flow regime, and Lollars Creek is the runoff flashy flow regime. Groundwater streams are usually more stable, and they have less seasonal drying. Runoff streams, however, tend to have frequent and intense drying during certain seasons. Runoff streams are therefore characterized by more variability than groundwater streams. Leasure et al. (2016) reported that groundwater flashy streams have less daily flow variability than the runoff streams and they never dried up completely. Figure 1 below provides more in-depth insight into the flow characteristic comparisons between flow regimes, including groundwater flashy and runoff flashy (Leasure et. al, 2016).

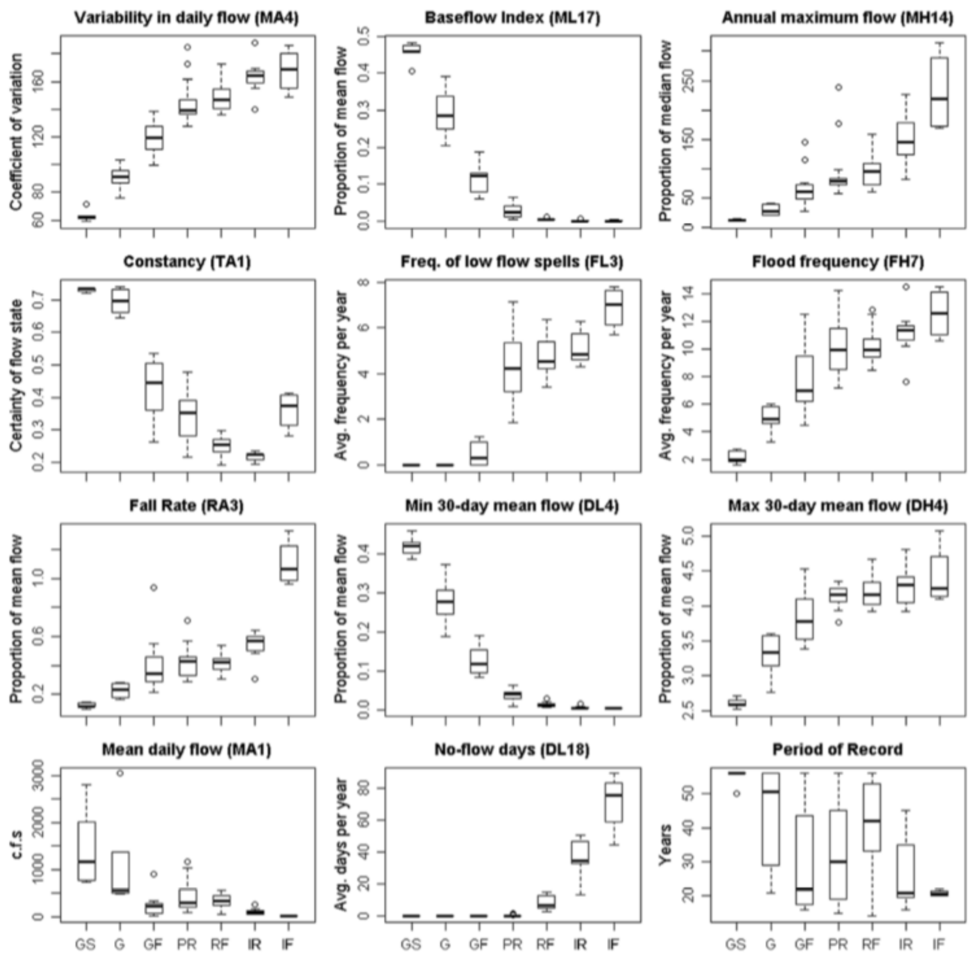


Figure 1. Flow metrics comparison between flow regimes (Leasure et. al, 2016). Groundwater Flashy = GF, Runoff Flashy = RF

This figure reveals that compared to the groundwater flashy flow regime, the runoff flashy flow regime has greater variability in daily flow, greater frequency of low flow spells, greater flood frequency, and greater no-flow days. It shows that the groundwater flashy flow regime, however, has greater constancy than the runoff flashy flow regime (Leasure et. al (2016).

Mikes Creek, according to the American Whitewater organization website, is a III-IV level difficulty stream that is 10.6 miles long. It has an elevation of 354 feet and has an average gradient of 120 fpm. The main drops of Mikes Creek occur in the first mile, and they include of four 10-15 foot waterfalls. Its coordinates are 36.630184, -94.145061. Lollars Creek, with an elevation of 1,237 feet, is located at 35.947527, -93.8468346.

Note: Citations for the websites used for the study sites information can be found underneath the references.

Organization Methods

To keep track of all of the subjects, it was determined that the best approach would be to assign labels including numerical indicators for both species type and specific species number to each subject. The number at the beginning of the label indicated the species type: 1 referred to duskystripe shiner and 2 referred to orangethroat darter. The number at the end of the label indicated which specific subject it was, and the word in the middle (Mike or Lollars) indicated the location of where the subject came from. Thus, the first duskystripe shiner observed from Mikes was labeled 1Mike1, the second was labeled 1Mike2, and so forth.

Initial Data

All subjects were caught using a SmithRoot Backpack Electrofisher. They were immediately put on ice and frozen upon capture, preserved in a freezer while not being used, and each was thawed before its dissection. When the subject had thawed enough to regain flexibility, initial measurements were taken. This included measuring the length of the subject in millimeters, followed by recording its weight in grams. Weight was taken by placing an empty aluminum weighing dish in the electronic scale, zeroing that weight, and then placing the subject inside. However, there were complications with weighing the whole fish subjects. Though initially the scale would read one concise measurement, in November of 2021 (during the data recording of the orangethroat darters from Mikes Creek) the scale would display an initial reading, and then would progressively decline without stopping. After doing everything possible to reset the scale calibrations and find a solution, it was determined by myself and my mentors that the best course of action was as follows: to weigh each subject after that point 3 separate times, record the initial weights displayed before the progressive decline started, and take the average of those three measurements. That average would be recorded as the final weight of the subject. When it came to weighing anything other than the whole fish subjects, such as the gut sac or gut sac contents, the scale did not display the previously described continuous decline in weight. It was therefore determined that all other weights recorded, besides the whole fish subject, could be done in one reading. We speculated that the reason for the whole fish subjects undergoing the continual weight decline had something to do with the subjects continuing to dry from their removal of the freezer, but this is not certain.

Isolating the Gut Sac

Once the initial measurements were recorded, the next step was to remove the gut sac from the subject. This was achieved by using scissors and/or a scalpel to create an anterior-to-posterior opening on each subject without penetrating too deep and cutting into the organs. The gut sac was then separated and cut out of the rest of the body cavity. Again, using an aluminum weighing dish, the gut sac was weighed, and that weight was recorded.

Isolation and Identification of Gut Contents

The next step was to use a dissecting microscope to locate and extract the food composites from the gut sac. While looking at the gut sac and food contents through the microscope, contents were observed and identified as either insect parts, algae, or remains of the gut sac. As identification occurred, the component being observed was placed in a weighing dish designated for the group it belonged to. However, before placing the insect parts/algae in their own respective aluminum weighing dishes, each dish was weighed and zeroed out so that only the weight of the insect constituents or algae would be measured when weighed after being completely extracted. Finally, the gut sac remains that did not comprise insect parts or algae were also weighed. Once those measurements were recorded, an image was captured of all insect components extracted for review and identification by my mentors.

Note: Algae contents were not further analyzed due to the fact that there were only 6 fish total (3 orangethroat darters and 3 duskystripe shiners) in the groundwater flashy flow regime that contained algae. Thus, there was no form of comparison for it since there was none found in either species in the runoff flashy flow regime.

Calculating Insect Occurrence

Percentages

Once all insect parts were identified, they were counted and each taxonomic order represented was tallied to a percentage out of all orders found per group. These percentages were then compared to one another for both species to see if there was a difference in the most prominent insect order represented and, how many orders were represented. Further, the percent occurrence of insect taxonomic groups found in the orangethroat darters was compared between the two flow regime locations, and then the same was done for the duskystripe shiners between the two flow regime locations. Comparisons were represented using a combination of bar graphing and pie charts.

Chi-Square Test

In order to determine if there was a difference in the types of insects consumed between flow regimes, a chi-square test was performed. Two separate tests were run, one for the orangethoat darters and one for the duskystripe shiners. The null hypothesis, H_0, is that the two populations follow the same distribution of insect types consumed. The alternative hypothesis, H_a, is that the two populations have different distributions of insect types consumed. If the null hypothesis is rejected, it would insinuate that species in the different flow regimes consume different types of insects. The significance level used was 0.05. The expected values were calculated by the online chi-square calculator utilized.

Insect Tallying for Chi-Square

Table 2A. Insect Identification Data for Duskystripe Shiners in the Groundwater Flashy Regime

Taxonomic Order	**Number of Insect Parts Identified**	**Further Subclassification (if applicable)**
Diptera	20	Family *Chironomidae*: 12
Trichoptera	9	Family *Hydropsychidae*: 8
Ephemeroptera	1	N/A
Plecoptera	1	N/A
Unknown	12	N/A
Total	43	

Table 2B. Insect Identification Data for Duskystripe Shiners in the Runoff Flashy Regime

Taxonomic Order	**Number of Insect Parts Identified**	**Further Subclassification (if applicable)**
Diptera	26	Family *Chironomidae*: 26
Trichoptera	4	Family *Hydropsychidae*: 1
Ephemeroptera	11	N/A
Plecoptera	2	N/A
Unknown	27	N/A
Total	70	

Table 3A. Insect Identification Data for Orangethroat Darters in the Groundwater Flashy Regime

Taxonomic Order	**Number of Insect Parts Identified**	**Further Subclassification (if applicable)**
Diptera	29	Family *Chironomidae*: 24 Family *Simuliidae*: 5
Trichoptera	7	Family *Hydropsychidae*: 4
Ephemeroptera	11	N/A
Unknown	27	N/A
Total	74	

Table 3B. Insect Identification Data for Orangethroat Darters in the Runoff Flashy Regime

Taxonomic Order	**Number of Insect Parts Identified**	**Further Subclassification (if applicable)**
Diptera	20	Family *Chironomidae*: 18 Family *Simuliidae*: 2
Trichoptera	3	Family *Hydropsychidae*: 2
Ephemeroptera	10	Family *Heptageniidae*: 2 Family *Baetidae*: 1
Trombidiformes	1	N/A
Odonata	1	N/A
Unknown	15	N/A
Total	50	

Calculating Insect Weight Significance

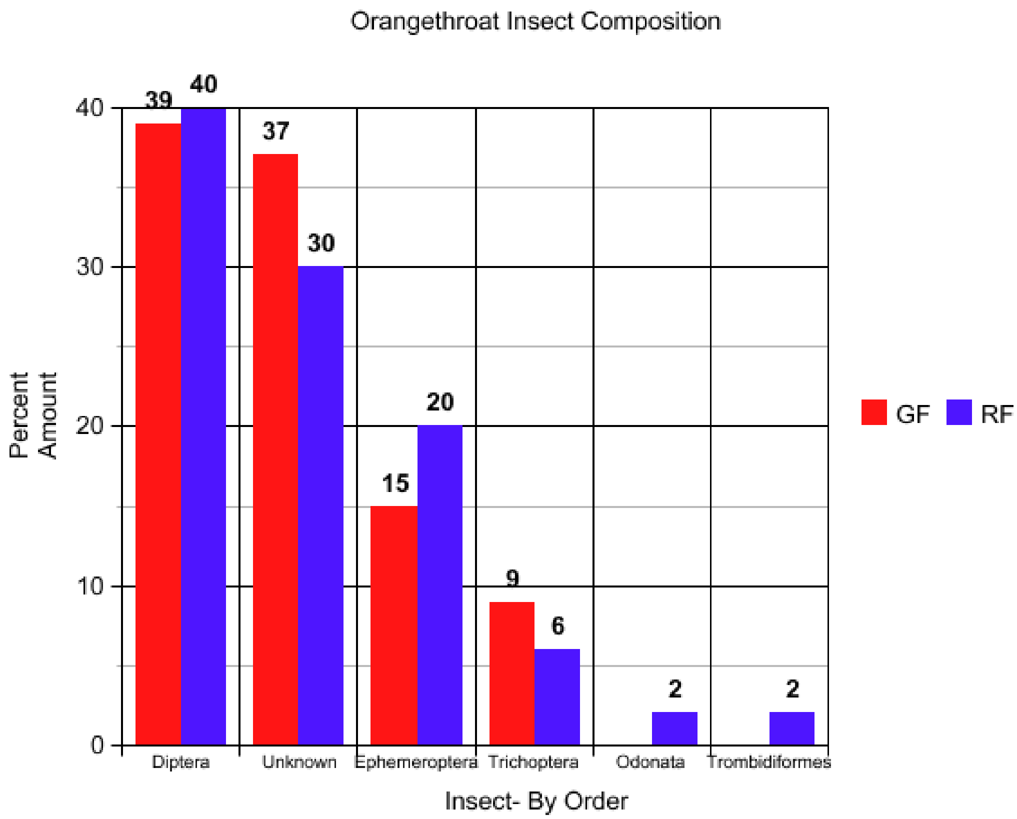
Two-Sample T-Test

A two-sample t-test was used to evaluate if there was evidence of a significant difference between the mean weights of insects found in the gut contents of the groundwater flashy populations and the runoff flashy populations. Because there are two groups of groundwater flashy vs. runoff flashy populations (orangethroat darters and duskystripe shiners), a two-sample t-test was run for both species. The null hypothesis, H_0, for each t-test is that there is no significant difference between insect weights found in the groundwater flashy populations and the runoff flashy populations. The alternative hypothesis, H_a, for each t-test is that there is a significant difference between the insect weights found in the groundwater flashy populations and the runoff flashy populations. If the null hypothesis is rejected, it would indicate that flow regime characteristics do cause noteworthy differences in the predatory outcomes of both species presented. The significance level used for these t-tests was 0.05.

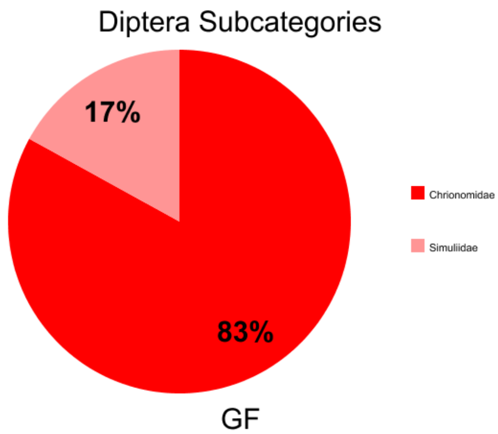
Results

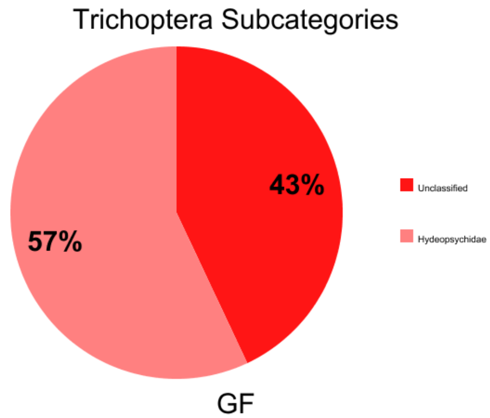
Orangethroat Insect Occurrences

Percentages

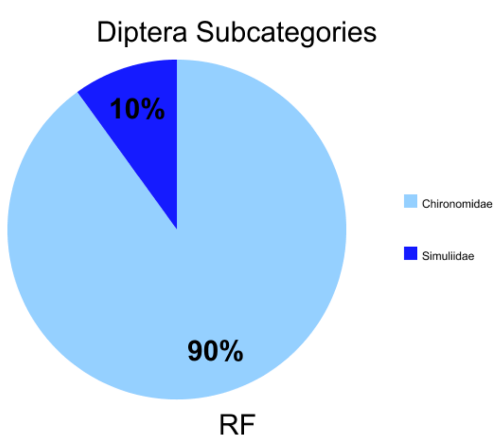


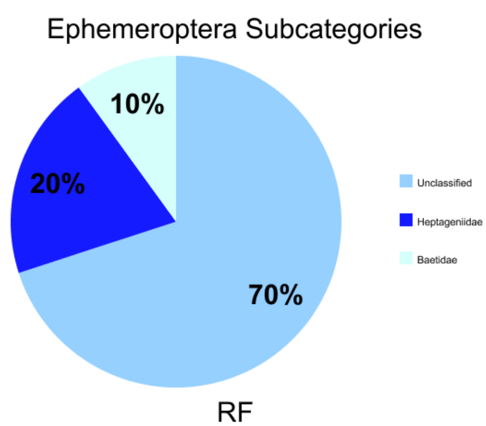
This diagram represents the types of insects found in the orangethroat darter subjects of both flow regimes, where GF refers to groundwater flashy and RF refers to runoff flashy. The insects were categorized based on what taxonomic order they belonged to, and the amounts of each order was put into a percentage to reveal their level of occurrence.

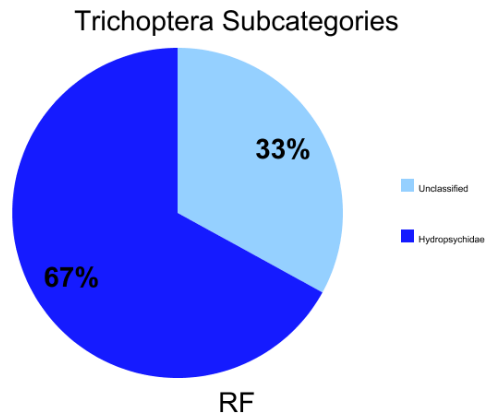




Within the insect composition of the orangethroat darters from the groundwater flashy (GF) regime, the *Diptera* and *Trichoptera* orders were further subclassified into families. Of the *Diptera* order group, 83% were classified as belonging to the *Chironomidae* family, and 17% were classified as belonging to the *Simuliidae* family. Similarly, 57% of the *Trichoptera* order was subclassified into the *Hydropsychidae* family, while the remaining 43% was not identified beyond the order it belonged to.







Subclassification also occurred in three of the insect order groups within the orangethroat darters from the runoff flashy (RF) regime. The *Diptera* fand *Trichoptera* order groups were again subclassified into families present, and the *Ephemeroptera* order saw subclassification as well. Of the *Diptera* order group, 90% were classified into the *Chironomidae* family, and 10% were classified into the *Simuliidae* family. Of the *Trichoptera* order group, 67% were classified into the *Hydropsychidae* family, and 33% were not further classified. Of the *Ephemeroptera* order group, 20% were classified into the *Heptageniidae* family, 10% were classified into the *Baetidae* family, and the remaining 70% were not further classified.

Chi-Square

Table 4. Chi-Square Test for Orangethroat Darters

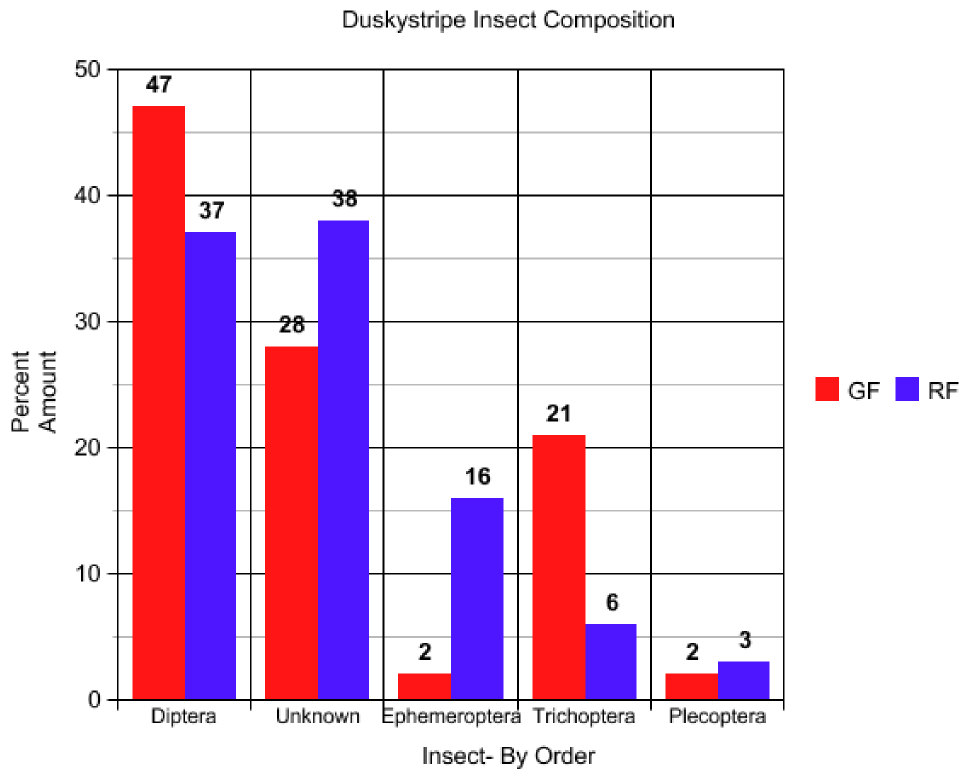
	Groundwater Flashy-Observed	**Groundwater Flashy-Calculated Expected**	**Runoff Flashy-Observed**	**Runoff Flashy-Calculated Expected**	**Observed Row Totals**
Diptera	29	29.2	20	19.76	49
Trichoptera	7	5.97	3	4.03	10
Ephemeroptera	11	12.53	10	8.47	21
Trombidiformes	0	0.597	1	0.403	1
Odonata	0	0.597	1	0.403	1
Unknown	27	25.07	15	16.94	42
Observed Column Totals	74		50		

Chi-Square statistic = 4.243

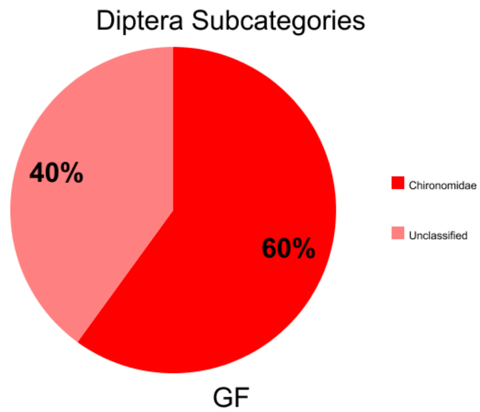
p-value = .515

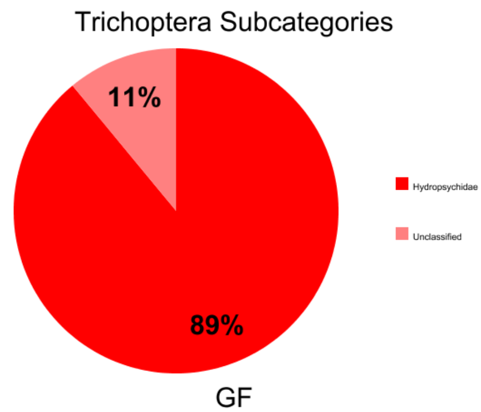
DuskyStripe Insect Occurrences

Percentages

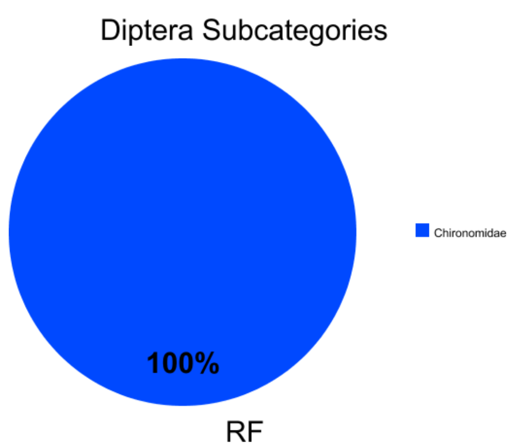


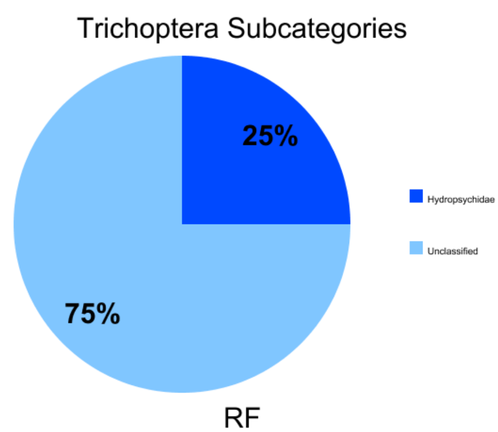
This diagram represents the types of insects found in the duskystripe shiner subjects of both flow regimes, where GF refers to groundwater flashy and RF refers to runoff flashy. The insects were categorized based on what order they belonged to, and the amounts of each order was put into a percentage to reveal their level of occurrence.





Again, the *Diptera* and *Trichoptera* order groups of the groundwater flashy (GF) duskystripe shiners were subclassified into families. The *Diptera* order was classified as 60% *Chironomidae* and 40% not further classified. The *Trichoptera* order was classified as 89% *Hydropsychidae* and 11% not further classified.





Finally, the *Diptera* and *Trichoptera* order groups of the runoff flashy (RF) duskystripe shiners saw further subclassification into families. 100% of the *Diptera* order insects were in the family *Chironomidae*, while the *Trichoptera* order was 25% *Hydropsychidae* and 75% not further classified.

Chi-Square

Table 5. Chi-Square Test for Duskystripe Shiners

	Groundwater Flashy-Observed	**Groundwater Flashy-Calculated Expected**	**Runoff Flashy-Observed**	**Runoff Flashy-Calculated Expected**	**Observed Row Totals**
Diptera	26	28.5	20	17.5	46
Trichoptera	4	8.05	9	4.95	13
Ephemeroptera	11	7.43	1	4.57	12
Plecoptera	2	1.86	1	1.14	3
Unknown	27	24.16	12	14.84	39
Observed Column Totals	70		43		

Chi-Square statistic = 11.3375

p-value = .023021

Insect Weight Significance

Two-Sample T-Test

The following charts reveal the data plugged into the two-sample t-test for both the duskystripe shiner insect weights and the orangethroat darter insect weights, respectively. The insect weights refer to the combined weight of insect parts found in the gut sac of each subject.

Duskystripe Shiner Two-Paired T-Test for Weight Significance

	Runoff Flashy	**Groundwater Flashy**	
Location/Subject	Insect Weight (g)	Insect Weight (g)	Location/Subject
1Lollars1	0.002	0.0206	1Mike1
1Lollars2	0.0024	0.0748	1Mike2
1Lollars3	0.0013	0.0689	1Mike3
1Lollars4	0.0015	0.0034	1Mike4
1Lollars5	0.0346	0.0018	1Mike5
1Lollars6	0.0047	0.0058	1Mike6
1Lollars7	0.0022	0.0059	1Mike7
1Lollars8	0.0016	0.0015	1Mike8
1Lollars9	0.0123	0.0032	1Mike9
1Lollars10	0.0104	0.006	1Mike10
1Lollars11	0.0041		
1Lollars12	0.0113		
1Lollars13	0.0105		
1Lollars14	0.0008		
1Lollars15	0.0023		
1Lollars16	0.0027		
1Lollars17	0.0064		
1Lollars18	0.0102		
1Lollars19	0.018		
1Lollars20	0.0062		
Mean	0.007275	0.01919	Mean
Standard Deviation	0.008002294	0.028315267	Standard Deviation

p-value: 0.0871

Orangethroat Darter Two-Paired T-Test for Weight Significance

	Runoff Flashy	**Groundwater Flashy**	
Location/Subject	Insect Weight (g)	Insect Weight (g)	Location/Subject
2Lollars1	0.0041	0.0002	2Mike1
2Lollars2	0.0056	0.0004	2Mike2
2Lollars3	0.0014	0.003	2Mike3
2Lollars4	0.003	0.02786	2Mike4
2Lollars5	0.0034	0.0027	2Mike5
2Lollars6	0.0021	0.0003	2Mike6
2Lollars7	0.0196	0.0005	2Mike7
2Lollars8	0.0043	0.0007	2Mike8
2Lollars9	0.004	0.0019	2Mike9
10		0.0003	2Mike10
11		0.0005	2Mike11
12		0.007	2Mike12
13		0.0014	2Mike13
14		0.0029	2Mike14
15		0.0002	2Mike15
16			
17			
18			
19			
20			
Mean	0.005277778	0.003324	Mean
Standard Deviation	0.005511982	0.007026099	Standard Deviation

p-value: 0.485

Discussion

Insect Occurrence

For each of the species analyzed in this study, both bar graphs depicting the type of insects consumed between the groundwater flashy flow regime and the runoff flashy flow regime showed similar trends in their occurrence. However, it was the chi-square test that went further than what the percentage graphs could show that really determined what was going on in terms of what types of insects were eaten between the two flow regimes. The orangethroat darter chi-square test resulted in a p-value higher than the significance level, meaning that orangethroat darters in the groundwater flashy flow regime did not statistically consume different types of insects than those in the runoff flashy flow regime. However, the duskystripe shiner chi-square test revealed a p-value lower than the significance level, meaning that duskystripe shiners did consume different types of insects between the two flow regimes. These results from the insect occurrences in the duskystripe shiners corresponded with the first part of my hypothesis: that differences in flow regime showed differences in predatory activity/foraging. However, the second part of my hypothesis (that there is greater success in predatory activity/foraging in the groundwater flashy flow regime than the runoff flashy flow regime) could not be proved or disproved from these results given that a chi-square test only evaluates whether or not differences occur, not which group being compared is more or less successful as a result of those differences. Further, these results presented by the duskystripe shiners could potentially reflect the work of Stein previously described: that the differences between the abiotic flow regime characteristics led to a difference in which types of insects the fish species preyed on in order to maximize their energy gain. However, more work needs to be done on this relationship to further prove it.

Insect Weight Significance

For both two-sample t-tests run to determine insect weight significance between the two flow regimes (one test for orangethroat darters and one test for duskystripe shiners), the p-value calculated was over the significance level (0.05). This means that for both orangethroat darters and duskystripe shiners, there was no statistical significant difference between the weight amount of found consumed in the groundwater flashy populations and the runoff flashy populations. However, this does not entirely disprove the idea that differences in flow regime can cause species to consume more or less amounts of prey. Further work needs to be done that compares the amounts of food consumed by types of species in all of the flow regimes before that notion can be considered a fact.

Relevance to Other Works

A study performed by Franssen, Gido, and Propst (2007) revealed how natural flows of a river were altered by human endeavors, and the ability for native prey to reproduce successfully declined greatly. The Colorado pikeminnow in that river are endangered, potentially due to these circumstances (Franssen et al., 2007). It is therefore important to understand how flow regime affects predation and foraging abilities of the aquatic species within them. As anthropogenic activities continue to reconstruct the natural components of our ecosystems, it is more beneficial for us to have an adequate understanding of the properties of those natural components (like the effect of flow regime on predation). The findings of my study show that certain biotic processes for species are different in different flow regimes, which means that creating differences in the flow characteristics of an aquatic ecosystem can result in the biotic processes of those species being inhibited. Thus, if natural aquatic environments become unnatural due to our transformations of them, we will have a better chance of knowing how to fix the problem if we know how the biotic and abiotic components of that environment work.

Diving even deeper into the systematics of human alterations and flow regime, Suen and Eheart (2006) discuss the ecological flow regime approach, which is essentially a model for management and planning of water resources that optimizes trade-offs between flow regime upkeep and human demands (Suen and Eheart, 2006). They describe the needs of the ecosystem as maximizing the likeness of flow regime after development to its predevelopment characteristics. If the results of my study and any similar studies to it, past or future, revealed that biotic processes were not dependent at all on the characteristics of the flow regime they are found in, then it would not matter as much how humans altered those flow regimes. But, because certain biotic processes (such as predation) are dependent on the flow regime they're found in, it is important that when we cause changes to the natural flow regimes we find, we will be able to change them in a way that is similar to the integrity of the original flow regime (Suen and Eheart, 2006).

Future Directions

I believe that much more work needs to be done in the study of how different flow regimes affect predator-prey relationships of fish species in order to fully finalize and accept these results when applying them to the entire construct of flow regime systematics. Where this study analyzed and compared only two flow regime types and two species types, more could be drawn from future studies that process and compare more flow regimes and more native species within those flow regimes. Also, it would be beneficial for future studies to utilize much larger sample populations of species in order to best reflect the true population dynamics, as well as utilizing more stream ecosystems.

A study was done on a river system in which a dam placed in that system gave direct insight in how the flow characteristic changes caused by the dam affected biotic assemblages (Bredenhand and Samways, 2009). Because the dam affected the flow characteristics of anything downstream of it (meaning upstream of the dam still showed natural flow characteristics), differences in biotic assemblages downstream of the dam were caused by the dam, while differences in biotic assemblages upstream of the dam were from natural causes (Bredenhand and Samways, 2009). Replicating a study such as this while incorporating the flow regime-predation relationship that was observed in my study could be a good idea for future research. Instead of having to look at flow regime differences between two different streams, one could look at the flow regime differences of one stream with a dam in it and assess how the differences in flow upstream and downstream of the dam affect the predator-prey relationship of species in that stream.

Flow regime and hydrology play an important role in environmental dynamism. The more adept we are at understanding environmental dynamism, the better we will be at endeavors such as protecting and preserving native species diversity and supporting the solidity of river ecosystems. Alteration of flow regimes is a significant threat to riverine systems, though with climate change, disturbances caused by human undertakings, and other environmental hazards, flow regime alteration is unfortunately inevitable. As our environments and ecosystems are constantly susceptible to digression by these things, it is our job to have the best knowledge of flow regime and all that flow regime affects so that we can adequately protect, preserve, and restore those natural spaces.

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