Size Selective Predation and its Effects on Zooplankton Populations

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ABSTRACT

Many lakes around the world have plankton communities that are structured by an ecological phenomenon known as size selective predation. Size selective predation is a form of predation that selects for prey of a specific desired size by the predator. Size selective predation can have an effect on both size distribution of the prey population as well as the composition of zooplankton taxa in a lake ecosystem. The overarching question being asked in this experiment is how the different zooplankton populations are affected under conditions where they are subjected to size selective predation. Within our study, we assessed the effects of size selective predation in two lakes in British Columbia and reproduced the natural phenomenon in the lab using live zooplankton and their predators to simulate interactions in the natural world.

Introduction

There are many forms of ecological interactions between predator and prey, and how those relationships leave an effect on both the populations of the predator and the populations of the prey (Brooks and Dodson, 1965). The main form of interaction we seek to analyze is size selective predation which is simply predation that is driven based on the size of the prey. In the scope of limnology, a common scenario is between fish and zooplankton.

Predatory fish are visual predators, meaning they use visual cues to locate prey. In this case, they use the visual component associated with zooplankton size as the main driver of predation in order to select their prey (Brooks and Dodson, 1965). Here we evaluated whether size selective predation could be structuring the size distribution and species composition of two lakes in southern British Columbia that differed in their predators.

The overall prediction is that there will be an effect on the size distribution of the zooplankton in the lakes (Detmer et al., 2016). This parallels the hypothesis which states there will be less of a density of larger zooplankton given the mechanics of size selective predation (Dodson, 1974b). As a result, we would expect to see a population with a smaller overall size in the lake data as well as the laboratory data. The densities of larger sized individuals will be reduced due to the fact that under this hypothesis, they would be more subject to predation as opposed to the smaller individuals. With respect to the overall composition of the taxa present in the lakes as well as the laboratory scenario, the dominant taxa would likely be the taxa that are smaller on average, as they would experience less of a loss due size selective predation.

Methods

This experiment required two procedures. The first was a field study involving two lakes while the other involved feeding zooplankton to a pet aquarium fish. The first lake in the field study is Shirley Lake and the second is Placid Lake which are both located in southern British Columbia. More specifically, they are located in the UBC Malcolm

Knapp Research Forest, which is situated near Maple Ridge, British Columbia in Canada. Shirley Lake can be described as an 8-meter-deep lake that has no presence of predatory fish. It has a Secchi depth of 3.5 meters. On the other hand, Placid Lake is a 7-meter-deep lake with the presence of predatory fish in the form of Cutthroat trout (*Oncorhynchus clarkii*). It has the same Secchi depth of 3.5 meters. Both lakes are similar in that they cover an area of about 1 hectare. Additionally, they are both surrounded by bogs with no urban development in the watershed. Some historical data that may be important is the fact that the entire area of both lakes has been subject to logging within the past century. The sampling data was taken on October 26th, 2019. To collect these zooplankton samples, the research team used 80 µm conical shaped nets (0.30 meters in diameter) specialized for catching zooplankton. These nets were used to take vertical tows in the deep hole of the lake. Each lake had two different replicates collected. These samples were carried out twice each for each replicate from 5 meters deep to the surface of the lakes. The samples of zooplankton were then collected and preserved using ethanol (EtOH) and the different taxa were identified and documented in the sample. The taxa that were found to be part of the lake samples were *Chaoborous, Diaptomus kenai, Diaptomus leptopus, Daphnia, Holopedium, Diaphanosoma, Bosmina* and *cyclopoid copepods*. Finally, the body lengths of each taxon were measured under a dissecting microscope. The body sizes and densities were compiled and documented in a data set.

Regarding our lab study, water samples from Lake Washington were collected consisting of 3 main taxa of zooplankton. These taxa include *Cyclopoids, Calanoids* and *Daphnia.* Lake Washington has a maximum depth of about 65 meters and a mean depth of about 33 meters. It has a mean width of about 2 km and an area covering about 8959 hectares (City of Seattle, n.d.). The sample of zooplankton was also caught using a zooplankton net, then the taxa in the sample were identified and measured with an ocular micrometer. From there, the live zooplankton sample was poured into an aquarium holding the teaching assistant's pet tetras. After four hours, the surviving zooplankton were strained from the aquarium, counted, and measured for body length.

Results

Figure 1 depicts the change in density of 8 different species of zooplankton in the two lakes. As can be seen, the data suggests that the composition of the zooplankton population has drastically changed with the presence of a predatory fish. We see that the density of *D. leptopus* decreased in Placid Lake. Additionally, we see in Shirley Lake that *Daphnia* are virtually not present at only 0.00238 individuals per liter. However, in Placid Lake, the density increases to about 2.5 individuals per liter. This shows that the presence of trout (i.e., predatory fish) has a large impact on the distribution of zooplankton present in the lake. However, depending on the specific species the effect can differ. The presence of predatory fish caused an increase in density for some taxa such as *Daphnia*, *Holopedium* and *Cyclopoid copepods*, while for the remaining taxa it either decreased or had no effect. The largest taxa, *Chaoborus,* was not present in high numbers in either sample, however we do see that across the lakes, the density of *Chaoborus* does experience a slight decrease in the presence of fish which is consistent with the hypothesis.

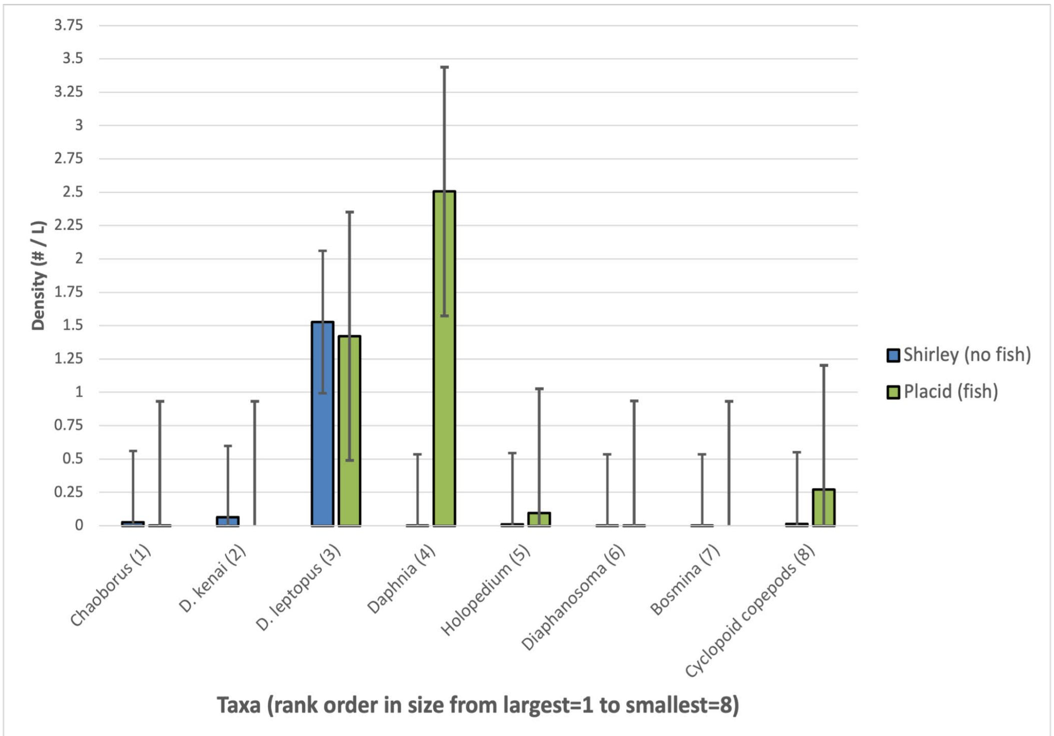

Figure 1: Average composition of zooplankton in Shirley Lake and Placid Lake across two replicates.

Table 1: Average composition of zooplankton for both lakes across two replicates shown numerically.

Taxon	Densities (number of individuals / L)	
	Shirley	**Placid**
(1) Chaoborus	0.0274	0.00143
(2) D. kenai	0.0631	0
(3) D. leptopus	1.53	1.42
(4) Daphnia	0.00238	2.51
(5) Holopedium	0.0107	0.0957
(6) Diaphanosoma	0.00119	0.00286
(7) Bosmina	0.00119	0
(8) Cyclopoid copepods	0.0155	0.27

For taxa such as *D. kenai, Bosmina*, and *Chaoborus,* the data show that predatory fish likely greatly reduced or eliminated these populations. We can see this based on how the density in Shirley Lake for *D. kenai* is approximately 0.06 individuals per liter and was not detected in Placid Lake. For *Bosmina*, the same can be said with the data showing a drop from 0.001 individuals per liter to 0 individuals per liter. Finally, with regards to *Chaoborus,* the data shows a drop from around 0.027 individuals per liter to about 0.0014 individuals per liter. Additionally, we see a slight change in diversity as a result of size selective predation. According to the data it shows that Placid Lake has slightly more diversity given the total population is spread out across more taxa. However, the difference is quite small.

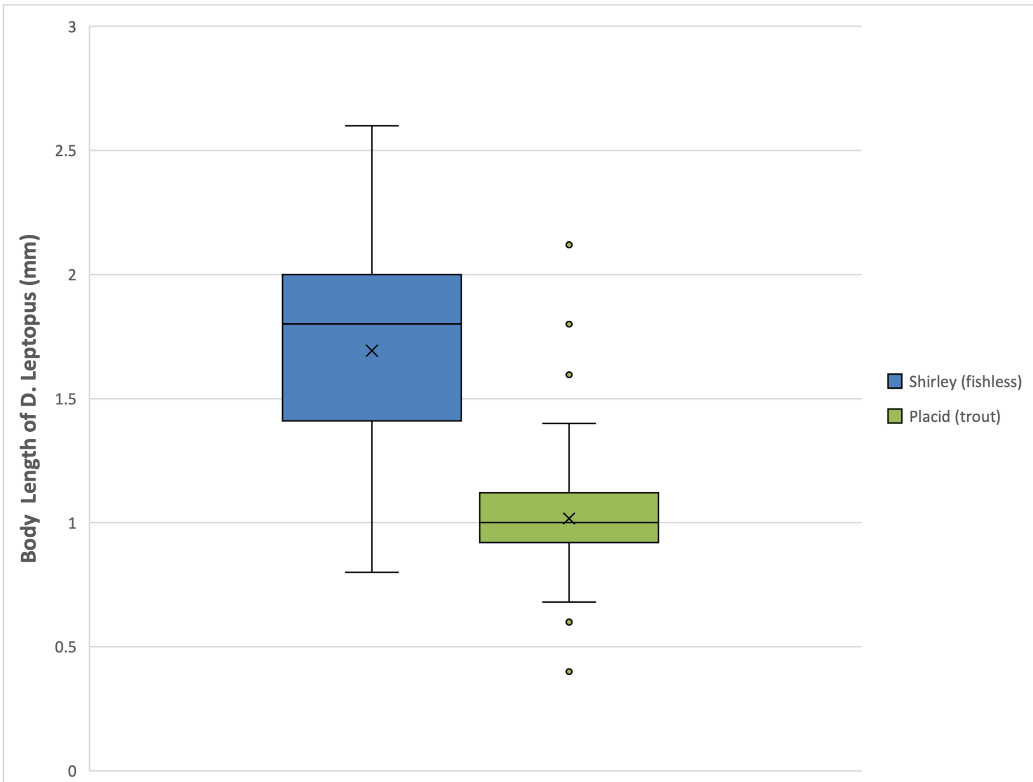

Figure 2: *D. Leptopus* Body Lengths in Placid Lake vs. Shirley Lake

There is a clear relationship on how body sizes compare between the two lakes specifically for *D. Leptopus* (Figure 2). The size distribution is much smaller in Placid Lake which shows that the predatory trout likely prefer larger zooplankton. As a result, this can explain why there is a higher average body length in Shirley Lake, where predatory fish are not present, vs. Placid Lake where the trout are present. Since the trout are not present in Shirley, the larger zooplankton are able to survive, which drives up the average body size. Some outliers were plotted to show that they were taken into consideration, and those outliers are specifically marked. However, the outliers were more prominent in Placid Lake because larger zooplankton are still present, however they are present in lower quantities.

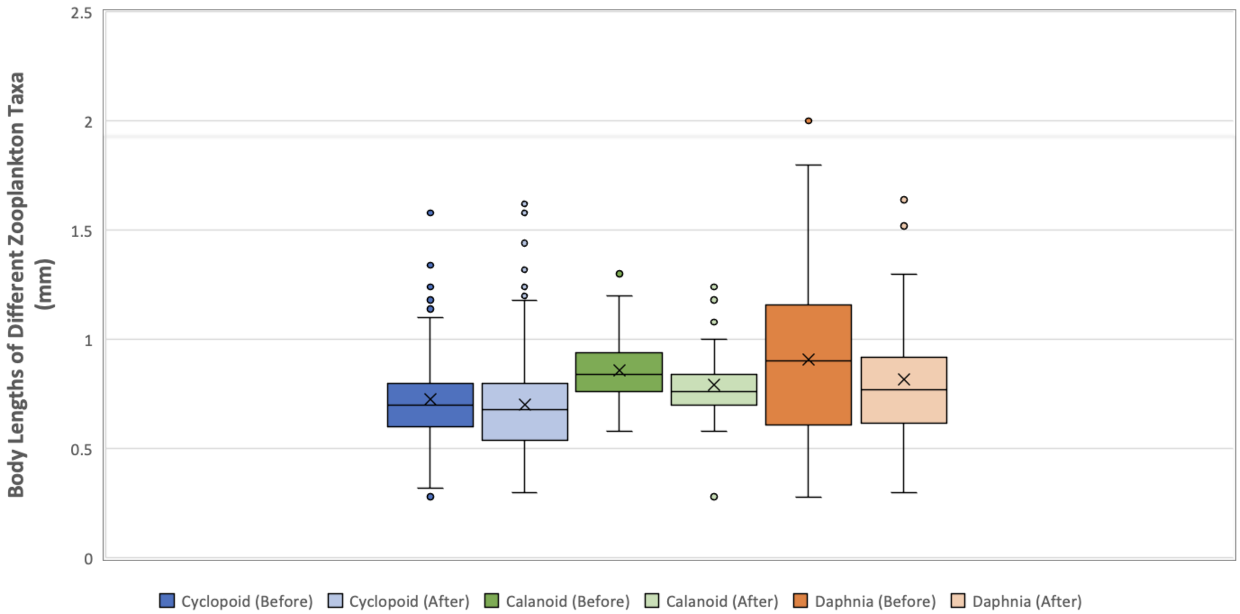

Figure 3: Body Lengths of Different Zooplankton from Lab Study (Before vs. After Presence of Fish).

Figure 3 depicts how body lengths compare across 3 different taxa of zooplankton during our own laboratory experimentation. We can see that for *Calanoids* and *Daphnia*, the mean body sizes as well as the variation in body size decrease after the presence of fish. In other words, we see an overall decrease in the size distribution of the taxa and less spread among the data. This lower spread can be attributed to the larger body sizes being eliminated from the population of Daphnia. This shows how predatory fish prefer larger body sizes for zooplankton which drives down the average body size as predation persists. However, for *Cyclopoids*, this was not the case as the sizes did not change. Regardless, the overall trend can indicate that size selective predation is present in ecosystems and the same phenomenon can be replicated in a laboratory environment.

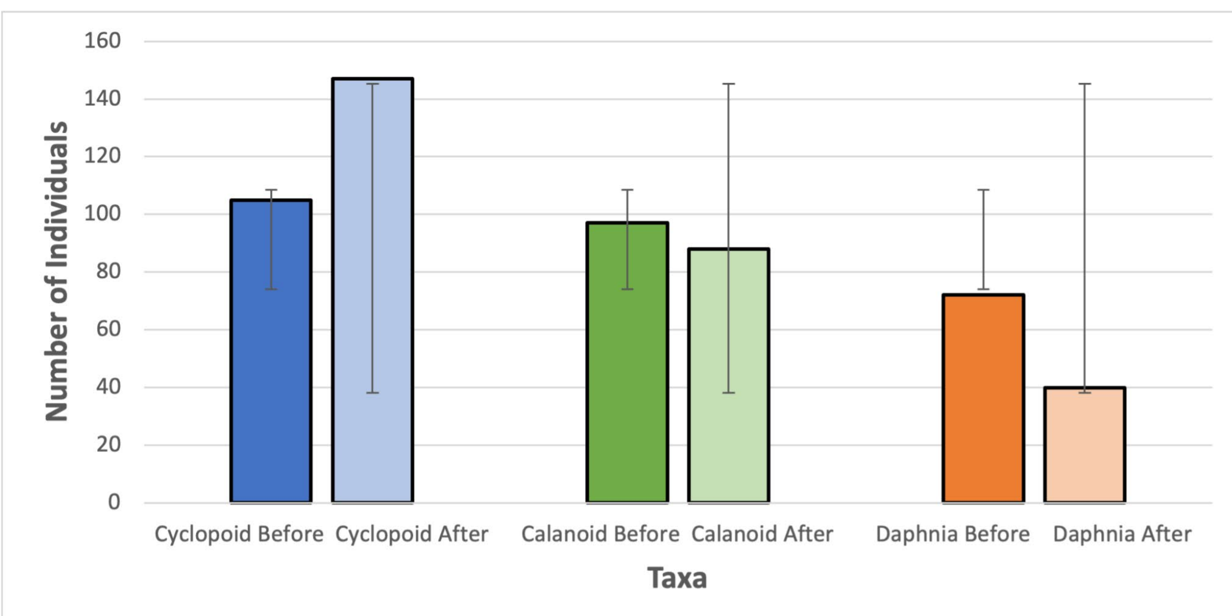

Figure 4: Composition of individuals by number in aquarium study.

Fish changed the species composition of the zooplankton fed to them. This data was compiled using the counts of the amount of data points we had for body length. What we observed is that the relative contributions of *Daphnia* to the zooplankton community declined in the presence of fish, while the relative abundance of cyclopoids increased. Additionally, *Calanoids* show an overall decrease, however the degree to which the decrease is reflected is less than that of *Daphnia.*

Discussion

The main goal of this study was to show how size selective predation can have a substantial impact on not only taxa composition of lake communities but also the size distribution as well. As can be seen, the data clearly shows that introducing a size selective predator into a lake can have these effects.

According to Dodson, size selective predation does have an effect on zooplankton populations. It was observed that it occurs among zooplankton species as well as vertebrate predators from higher trophic levels (Dodson, 1974b). In our study, we did not focus on the ecological interactions among zooplankton but rather, the interactions between zooplankton and vertebrate predators. Dodson states that a large portion of the observed size selective predation was due to the presence of the copepod *Diaptomus shoshone* which has a larger body size than its prey. This copepod preys on two different species of *Daphnia*: *D. minnehaha* and *D. middendorffiana*. According to Dodson's findings, the copepod selects for the smaller species (*D. minnehaha*) with regards to predation (Dodson, 1974b). This reflects the opposite trend of what we have seen in our study, which demonstrates that size selective predation in general selects for larger individuals as exhibited by the negative trend in overall average body size. Nonetheless, it is still important to note that although this trend is opposite to our results, the scope of this trend is more focused on interactions between two zooplankton species as opposed to zooplankton and vertebrate predators.

However, Dodson's study also gives credit to vertebrate predators such as amphibians, birds and especially fish for size selective effects. Given that the copepod preys on the smaller *D. minnehaha*, in the absence of vertebrate predators, *D. minnehaha* populations are decreased while *Diaptomus shoshone* populations are increased. In contrast, in the presence of vertebrate predators, *Diaptomus shoshone* is preyed on by vertebrates and therefore experiences a decrease in population which causes the populations of its prey to rebound (Dodson, 1974b). This concurs with our findings showing that vertebrate predators select for larger individuals which can completely alter the species composition found in the lake water as displayed in Figure 1.

The data in Figure 1 and Table 1 demonstrate that measuring the densities of these taxa in the natural world (British Columbia) can show an effect of the predator. We saw that the densities are drastically different for certain species with and without the presence of a predator. This is a perfect example of how size selective predation can have such a large impact at different trophic levels of an aquatic ecosystem.

An assumption that had to be made, however, is that Shirley Lake and Placid Lake are similar environments despite being two separate lakes. Although the statistics of each lake given above were very similar including mean depth and area, there could be a confounding factor that was not taken into consideration. This confounding factor could skew the data to allow for false conclusions. The assumption that these lakes are truly near-identical had to be made in order to draw these conclusions. The same assumption had to be made for the six alpine ponds used in the Dodson study. In an ideal scenario, it would be better to treat a real lake with the same treatment in the lab, so that we can use the same body of water and the same zooplankton population and treat it with size selective predators (the fish). This would allow for conditions that would be closer to identical in order to ensure the most accurate data and findings. However, this solution would be very expensive and also possibly destroy ecosystems due to the introduction of a possible invasive species (the predator). The Figure 2 data further rectifies the findings by going greater in depth for one specific species. We can clearly see that size-selective predation is at play as the size distribution is much lower overall in the lake that had the trout.

The lab data, while not in a natural environment, can be used to better represent scientific principles. This is because it keeps the conditions uniform throughout the duration of the observation period. We can see that for 2 of the 3 taxa that were taken into consideration (*Calanoids and Daphnia*), the data exemplifies that the size distribution decreases overall with the introduction of fish into the environment meaning that fish do feed based on size and they do not feed on random zooplankton individuals. The population data that accounts for the raw number of individuals for each taxa agrees with the trend as well given that it depicts a lower amount of individuals for the same 2 taxa mentioned previously. As mentioned prior, the main issue with this data is how *Cyclopoids* actually had a higher count after fish were introduced especially when we used a closed environment (i.e. the fish tank). This is likely due to some form of counting error. In future experimentation, it would be important to also assess morphological differences in addition to size to truly assess the impacts of size selective predation. Certain species have been shown to develop defense features such as in order to prevent predation from larger vertebrates (Dodson, 1974a). Additionally, behavioral changes have also been observed in similar conditions such as differential reproductive patterns and the production of diapausing eggs specifically for a species known as *Daphnia pulicaria* (Gelinas et al., 2007). A full top-down assessment of the results would allow for a greater understanding of the impacts of size selective predation.

Conclusion

Overall, our study confirms the prevailing theory of size selective predation. Despite the fact that the reference studies focus on both inter-zooplankton interactions as well as interactions between vertebrate predators and zooplankton, we see that the principle of size selective predation can occur at various trophic levels. According to the Dodson study, it can occur bidirectionally showing that size selection can select for larger or smaller individuals. However, our study only exemplified evidence of unidirectional size selective predation in favor of larger individuals. Regardless, this information can be used and applied to other aspects of limnology as well. It aids in understanding the reasoning for certain trends in zooplankton population distribution in bodies of water (Detmer et al., 2016). Additionally, understanding the feeding patterns of fish and how zooplankton populations are affected by such is important when attempting to predict or assess lake conditions for specific lakes. While each lake is unique in its own way, with its own specific set of conditions as well as chemical, biological and physical properties, the same basic principles can be applied to come to further conclusions.

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