Fish Diets in Tenderfoot Lake and Tenderfoot Creek: A Comparative Study

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Abstract

Recreational fishing is a major source of revenue for states throughout the upper Midwest and Great Lakes region, which increases the need for effective management options. An important factor of managing a fishery is understanding what the fish are feeding on. This study analyzed the diets of three baitfish species – bluegill sunfish, pumpkinseed sunfish, and yellow perch – in a lake and connected stream. Fish were sampled from the lake and the stream using seine nets, fyke nets, and angling methods. Diet samples were taken via gastric lavage or dissection. Comparisons of the contents of both sampling methods showed that the lavage samples were an accurate subsample of the actual stomach contents ($p>0.05$). Analysis of stomach contents found that fish species sampled in the lake were consuming the same average mass and percentage of both invertebrates and vegetation ($p>0.05$). However, fish captured in the lake consumed a higher ratio of invertebrates compared to vegetation than their stream-dwelling counterparts ($p<0.01$). Nevertheless, it is evident that fish in a stream and a lake are heavily dependent on invertebrates as their primary food source.

Introduction

Recreational angling contributes billions of dollars to state economies throughout the upper Midwest and Great Lakes region. In 2011, Michigan anglers spent nearly $2.5 billion on fishing-related items and travel (Allen et al. 2013), and the sport fishing industry in Wisconsin contributes $2.75 billion annually to the state's economy (Wisconsin DNR 2010). A portion of that annual income is allocated to agencies responsible for maintaining and improving the quality of Midwestern fisheries. One important factor of fisheries management is ensuring that the fish present have the food necessary to grow and reproduce.

While large piscivorous fish are typically the targets of recreational anglers, these fish are dependent on smaller forage fish, commonly known as baitfish, to produce a useful energy source (Engelhard et al. 2014). A subset of these baitfish, known as panfish, double as a food source for anglers interested in harvesting some of their catch. Panfish are abundant and easy to catch, and make for a good meal to the fishermen willing to clean them (Isaacson 1995). Panfish typically eat aquatic vegetation, macroinvertebrates, minnows and zooplankton. Ensuring that these fish have enough food to grow not only promotes growth of large piscivorous game fish, but also provides a quality fishery for catch-and-clean anglers.

Ensuring that organisms at all trophic levels have adequate food helps to promote better water quality. When a lake has a healthy population of piscivores, the population of planktivores is suppressed, which allows herbivorous zooplankton species to thrive (Carpenter et al. 1985). These zooplankton then control the phytoplankton in the lake, promoting clearer water. However, if the herbivorous zooplankton population is too low, the lake will not only be at an increased risk for algal blooms that decrease the water quality, but the herbivorous zooplankton will also run the risk of starving, which would in turn decrease the food available for the predatory fish species.

Aquatic habitats that include a lake and a connected stream provide different habitat options for the organisms that inhabit the waters. In the lake habitat, the water experiences thermal stratification, which in turn alters levels of dissolved oxygen throughout the year (Wilhelm and Adrian 2008). This limits where certain organisms can survive based on their tolerance for high- or low-oxygen conditions. However, the shallow streams that flow out of these lakes do not experience this stratification. This results in consistent oxygen concentrations throughout the entire stream. These streams also typically have dense vegetative growth throughout the entire channel, as opposed to the limited littoral zone in the shallow waters of lakes. This large littoral zone provides habitat and shelter for various organisms, including baitfish that use the vegetation to hide from predators and feed and predatory fish that use the thick cover as ambush points for feeding on the baitfish (Hanisch et al. 2012).

Along with providing different habitats, lake and stream ecosystems depend on different food web drivers as well. In most cases, lakes will depend on a large number of species of phytoplankton to initiate the flow of energy from primary producers to apex predators (Martinez 1991). The large open-water basins of lakes allow phytoplankton populations to flourish and drive the food web. These phytoplankton provide food for zooplankton and macroinvertebrates. Conversely, small, low-gradient streams typically associated with these lakes are dependent on macrophytes to anchor the food web. These relatively large aquatic plants provide food for herbivorous and omnivorous organisms and create a habitat suitable for bacterial colonization (Schmid-Araya and Schmid 2000). These bacterial colonies provide added nutrition to organisms that consume the macrophytes, while also directly supplying food to macroinvertebrates.

This study examined the diets of three different fish species found in both Tenderfoot Lake and Tenderfoot Creek: bluegill sunfish, pumpkinseed sunfish, and yellow perch. The objective of the study was to determine the diet composition of these three fish species and determine how that composition changed depending on where the fish were sampled. It was hypothesized that the diets of the fish sampled in Tenderfoot Lake would be different from the diets of the fish sampled in Tenderfoot Creek, with lake fish containing mostly invertebrates and fish from the creek containing mostly phytoplankton.

Methods

Study Site

This study was conducted on Tenderfoot Lake and Tenderfoot Creek, located on the University of Notre Dame Environmental Research Center (UNDERC) on the border of Wisconsin and Michigan's upper peninsula. Tenderfoot Lake is a eutrophic glacial lake located almost entirely in Vilas County, Wisconsin. The Ontonagon River flows into the South end of Tenderfoot Lake from Palmer Lake. Agricultural practices within the lake's drainage, as well as housing developments along the lake's shoreline, contribute to the eutrophic state. While there is no public boat access directly on Tenderfoot Lake, it is easy to access the lake through the Ontonagon River from Palmer Lake. Tenderfoot Lake experiences moderate fishing pressure, particularly for the lake's large predator species: muskellunge, northern pike, and walleye.

Tenderfoot Creek flows out of the North end of Tenderfoot Lake into Gogebic County, Michigan. The stream eventually flows into the Ontonagon River before draining into Lake Superior. Tenderfoot Creek is shallow and has a slow flow rate due to the low gradient of the streambed. Because of dense vegetation in the stream, as well as along the littoral zone of the lake, Tenderfoot Creek is not easily accessible by boat. Furthermore, because the area surrounding the stream is forested private property, there is no easy access to the stream from shore either, which results in minimal fishing pressure.

Samples taken from Tenderfoot Lake were collected near the dock at the UNDERC wet lab (Fig. 1). This area sees moderate human traffic, which could influence the number and species of fish present. Samples taken from Tenderfoot Creek were taken near the road that crosses the stream (Fig. 1). The stream passes under the gravel road through multiple culverts with wire fences to prevent beaver activity. This road is frequently traveled by the inhabitants of UNDERC. These factors could also contribute to the number and species of fish present in this section of the stream.

Data Collection

Fish were collected using three methods: seine netting, fyke netting, and angling. The majority of the fish were caught using a seine net in shallow water along the shoreline of Tenderfoot Lake and Tenderfoot Creek. However, the soft and unstable streambed of Tenderfoot Creek made seine netting difficult. To obtain a greater sample size from Tenderfoot Creek, a fyke net was set for 24 hours. The net was anchored to the shore and set perpendicular to the bank. Because seine net samples on Tenderfoot Lake favored yellow perch, the fyke net was also set on the lake for 18 hours. Due to time constraints and a necessity for a larger sample size near the end of the research period, three bluegill sunfish and one pumpkinseed sunfish were also taken with hook and line. In an attempt to reduce bias in forage preferences, no live bait was used when angling.

Gastric lavage technique was used to analyze the diets of fish collected. To perform the lavage, a piece of rubber tubing was attached to the end of a syringe and inserted into the fish's stomach through the throat. Water was then squeezed from the syringe into the stomach. Lightly squeezing the fish's stomach when the tubing was removed and holding the fish with its mouth downward emptied the contents of the stomach into a strainer.

Ethanol was used to rinse the stomach contents in the strainer before transferring them to a plastic bag with ethanol. This method was useful only for examining the food the fish had eaten recently. In order to ensure that the lavage contents were an accurate subsample of the actual fish diets, 18 fish were dissected and their entire GI tract analyzed. All stomach contents, collected via gastric lavage or dissection, were examined under a dissecting microscope and sorted into two categories: vegetation and invertebrates.

Statistical Analysis

Data analysis included comparing the average mass of vegetation and invertebrates between lake and stream fish, as well as a ratio of invertebrates to vegetation. When calculating the ratio of invertebrate mass to vegetation mass, in order to deal with samples that included no measurable mass of vegetation, the ratio was calculated by dividing the invertebrate mass by 0.0001. In order to compensate for some fish simply containing more food at the time of collection than others, percentages of total identifiable stomach contents were also calculated. In order to normalize these percentages, a transformation was applied to each percentage using the following equation:

$$\arcsin(\mathrm{sqrt}(x+0.0001)),$$

where x is the original percent vegetation or percent invertebrate mass. However, some of the fish contained no measurable mass of either vegetation or invertebrates. This caused an error in the calculation due to the arcsine of a number larger than one being an imaginary number. In this case, the addition of 0.0001 was omitted.

Paired t-tests were completed to compare the fish from the lake to the fish from the stream for both mass of vegetation and percent vegetation. Paired t-tests wee also conducted to compare mass of invertebrates and percent invertebrates in lake fish versus stream fish. A two-sample t-test was used to compare the ratios that were calculated. Finally, a two-sample t-test was completed to compare the lavage samples to the dissected samples. This final t-test used the transformed percentages for the fish collected only from Tenderfoot Lake due to sample size. This was to ensure that the lavage samples were an accurate subsample of the total stomach contents found in the dissections.

Results

There was no significant difference between fish sampled in Tenderfoot Lake and Tenderfoot Lake for average mass of vegetation ($p=0.0606$)(Fig. 2), percent vegetation ($p=0.4461$)(Fig. 3), average mass of invertebrates ($p=0.5624$)(Fig. 4), or percent invertebrates ($p=0.4452$)(Fig. 5). However, Tenderfoot Lake did show a higher ratio of invertebrate mass compared to vegetation mass ($p=0.0097$)(Fig. 6). There was no significant difference between lavage and dissection samples for percent vegetation ($p=0.8410$)(Fig. 7) or percent invertebrate ($p=0.8470$)(Fig. 8).

Discussion

There was no statistical difference in either overall mass or percentage of diet between fish sampled from Tenderfoot Lake and Tenderfoot Creek for either vegetation or invertebrates. This is at least partially due to the large variation in the data collected, especially when considering overall mass. These findings did not support the hypothesis that the diets of fish sampled in the lake would be different than the diets of the fish sampled in the stream. However, these findings were supported by Ravinet et al. (2013). These authors found that while stickleback from a lake and stream foraged on significantly different species, invertebrates were the primary food source in both habitats. Fish in Tenderfoot Lake had a significantly higher ratio of invertebrates to vegetation than fish from Tenderfoot Creek, but both groups displayed an average ratio greater than one. This indicates that fish in Tenderfoot Lake consume more invertebrates in relation to vegetation compared to fish from Tenderfoot Creek. However, both groups of fish displayed an average ratio greater than one, which indicated that the fish in both locations relied most heavily on invertebrates for food. This result supported the hypothesis that fish sampled in the lake would rely most heavily on invertebrates for food, but did not support the hypothesis that fish sampled in the stream would be highly dependent on plankton for food.

There was no significant difference in the average percentage of vegetation and invertebrates between the lavage and dissection sampling methods. In this case, no difference was the anticipated result. This showed that sampling via gastric lavage provided an accurate subsample of the actual gut contents for each fish.

Bluegill and pumpkinseed, both members of the sunfish family, were dependent on invertebrates for the majority of their diet. This was supported by the findings of Tetzlaff et al. (2011), who found that these fish species relied heavily on benthic macroinvertebrates for their diet. Along with these aquatic insects, the authors also found that these panfish would consume organisms such as juvenile crayfish. Sampled fish from Tenderfoot Lake and Tenderfoot Creek were found to contain juvenile crayfish, as well as mollusks such as snails and freshwater clams, typical of sunfish species that reside in the shallow littoral zone (Berchtold et al. 2015).

The diets of the sampled yellow perch, many of which were very small, also consisted primarily of invertebrates. Both zooplankton and macroinvertebrates were found, similar to the findings of Roswell et al. (2013). The diets of the sampled perch also contained some aquatic vegetation. As a piscivorous fish, it was expected that some of the perch would contain some vertebrate fish in their diets (Mirza and Chivers 2001). This did not hold true for the yellow perch sampled in this study, but this is likely due to the small size of the majority of the fish sampled.

While this study did not yield the results that were expected, it is still possible that fish in these bodies of water still exhibit expected behaviors. Scientists have long struggled to accurately quantify fish gut contents, and some would argue that investigating percent frequency is a more effective method (Baker et al. 2014). Furthermore, typical fish diet analysis studies typically have sample sizes upwards of 200 individuals (Urquhart and Koetsier 2014, Willis et al. 2015), whereas this investigation only used 58 total individuals. Most other studies also frequently classify diet items more specifically, such as identifying organisms to order or family, which allows researchers to determine whether fish are truly consuming the same food sources. Time constraints and other commitments limited the number of samples that were able to be collected, as well as the specificity of diet classification. Larger sample sizes would also allow for analysis within species, rather than grouping three distinct species together. This would allow for more accurate interpretation, as fish diets vary greatly between species. Finally, a larger sample area would ensure that any trends discovered were applicable to the entire species in a water body, rather than a single population.

While lakes and streams provide different habitats for the organisms that inhabit them, it is still possible for members of the same species to be found in both habitats. However, due to differing environments, different food sources are available. Nevertheless, it appears that three panfish species – bluegill sunfish, pumpkinseed sunfish, and yellow perch – rely most heavily on invertebrates for food in a lake and connected stream along the Wisconsin-Michigan border. By understanding what organisms these fish rely on for food, it is possible to employ management techniques that promote healthy populations of not only the fish, but also the invertebrates they feed on. Because management for invertebrates typically focuses on water quality (Maret et al. 2008), this would lead to an overall improvement in the resource as a whole.

Acknowledgements

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Figures

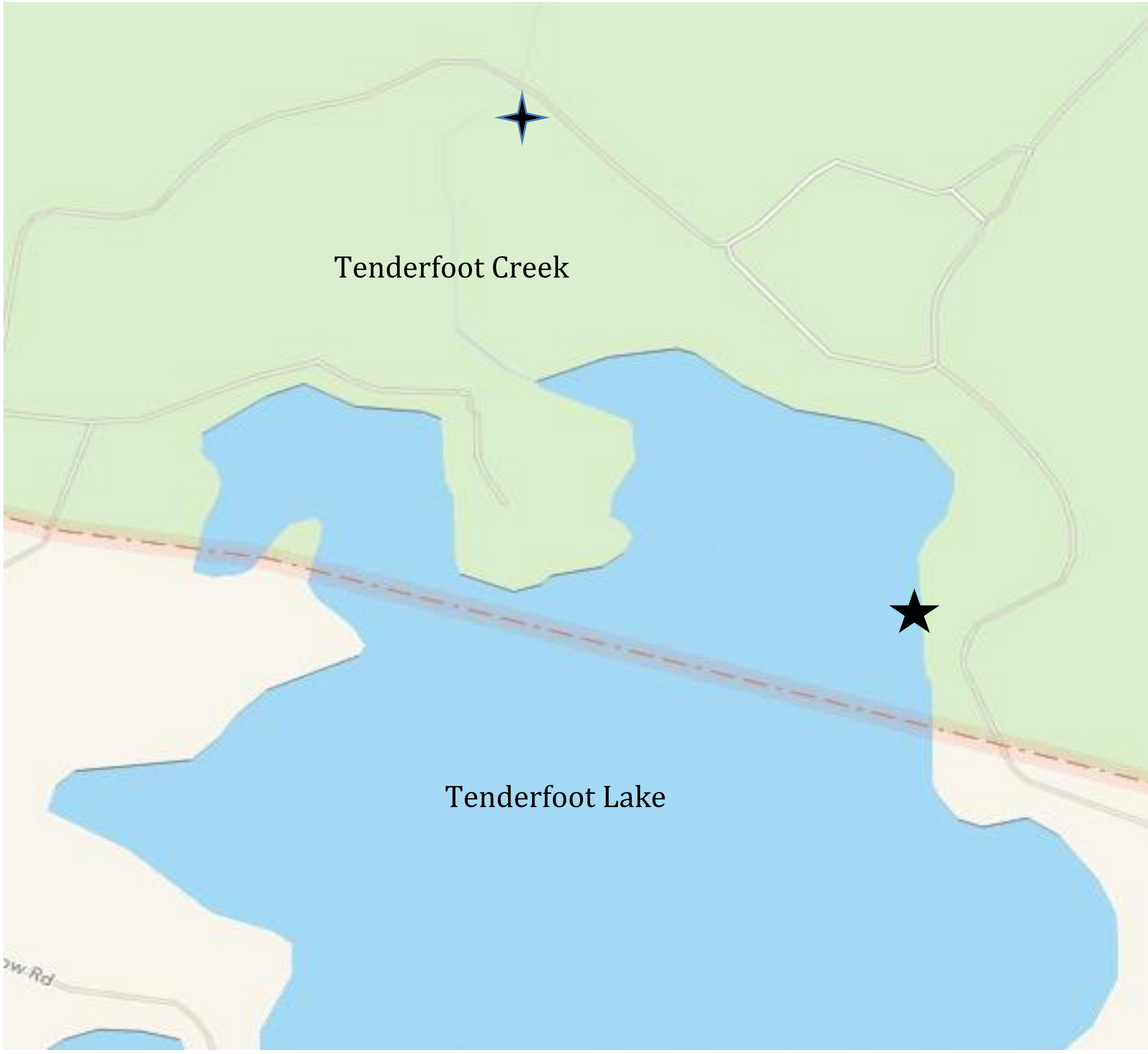

Fig. 1. Map displaying sample sites on Tenderfoot Lake (five-point star) located in Vilas County, WI and Gogebic County, MI, and Tenderfoot Creek (four-point star) located in Gogebic County, MI. State boundary indicated by red dashed line.

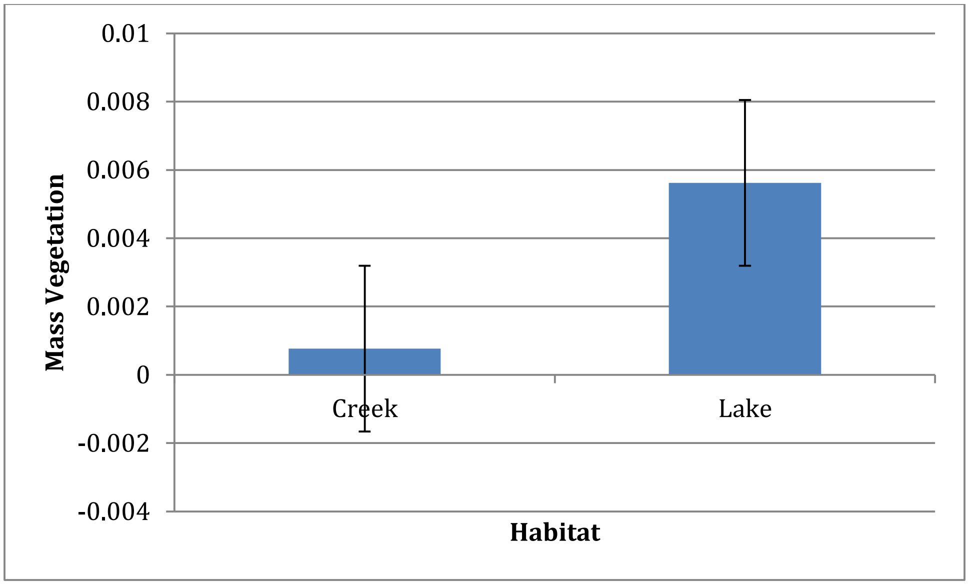

Fig. 2. Average dry mass of vegetation in diets of sampled fish. Error bars represent standard error. Average mass of vegetation was not significantly different between the creek and the lake ($p>0.05$).

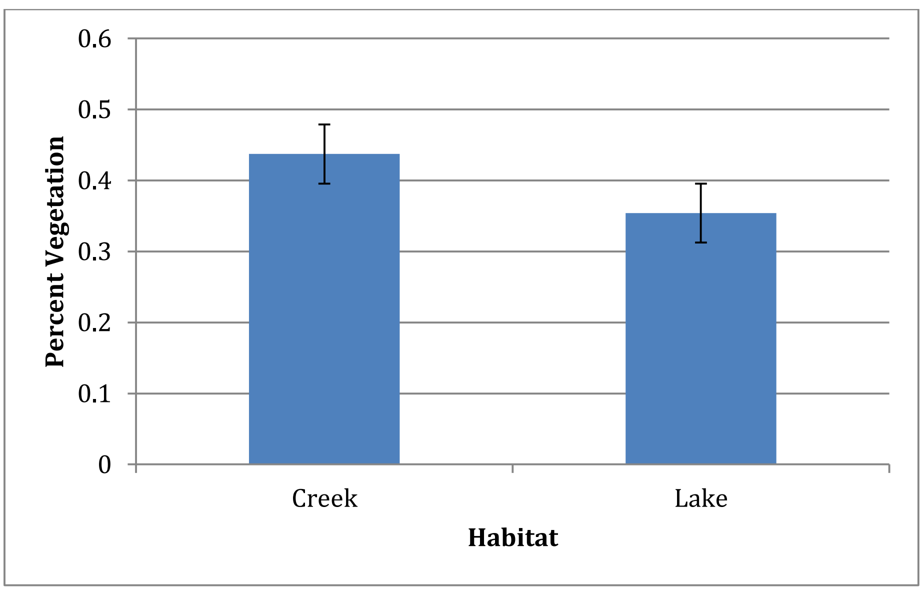

Fig. 3. Average percentage of diets made up of vegetation. Error bars represent standard error. Average percentage of vegetation was not significantly different between the creek and the lake ($p>0.05$).

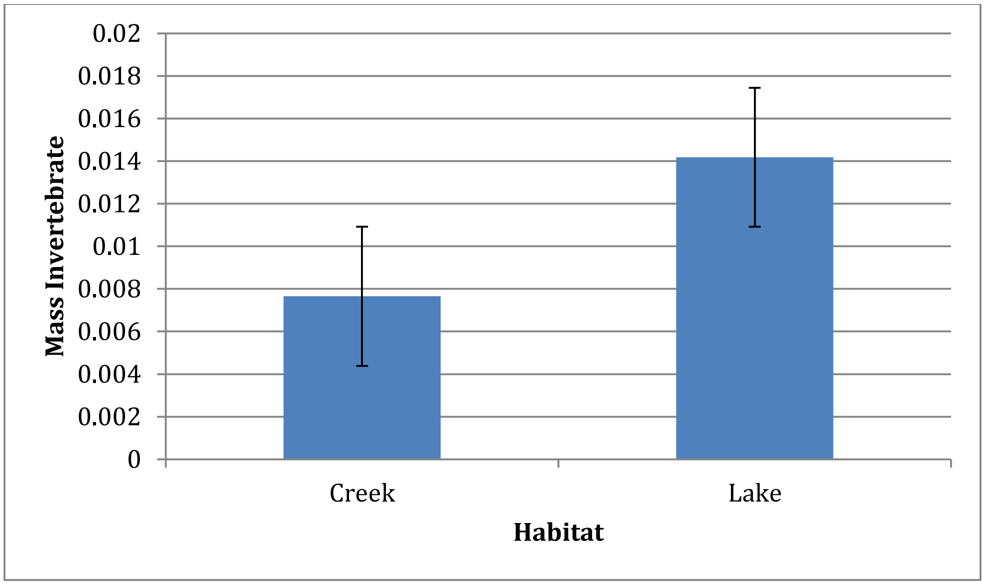

Fig. 4. Average dry mass of invertebrates in diets of sampled fish. Error bars represent standard error. Average mass of invertebrates was not significantly different between the lake and the creek ($p>0.05$).

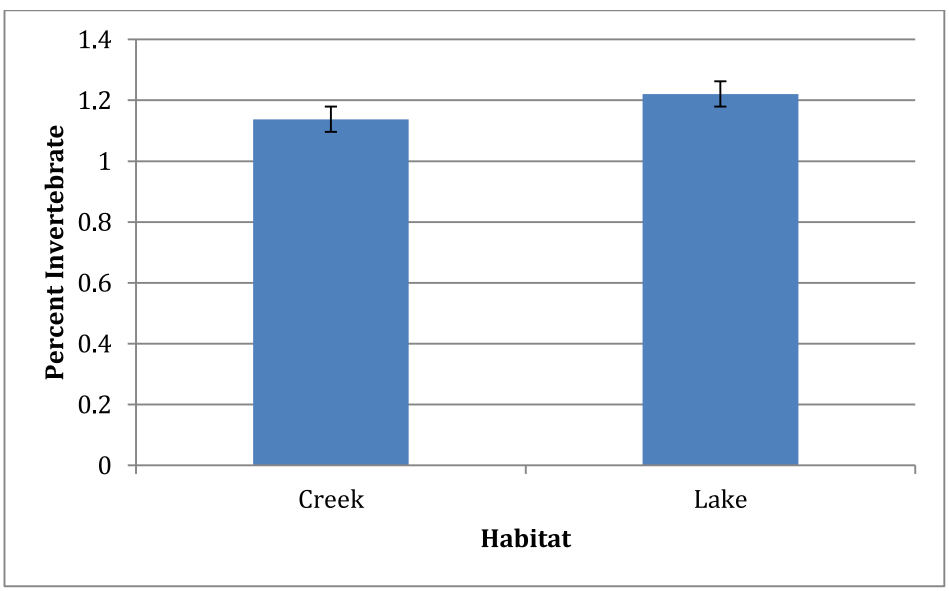

Fig. 5. Average percentage of diets made up of invertebrates. Error bars represent standard error. Average percentage of invertebrates was not significantly different between the lake and the creek ($p>0.05$).

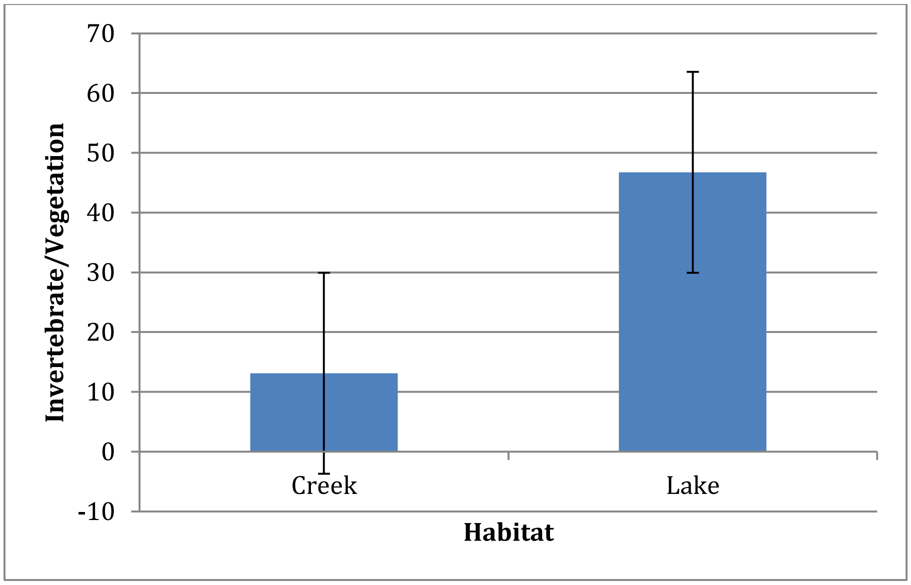

Fig. 6. Ratios of invertebrate dry mass to vegetation dry mass. Error bars represent standard error. Ratio of invertebrate to vegetation mass was significantly different between the lake and the creek (p<0.01).

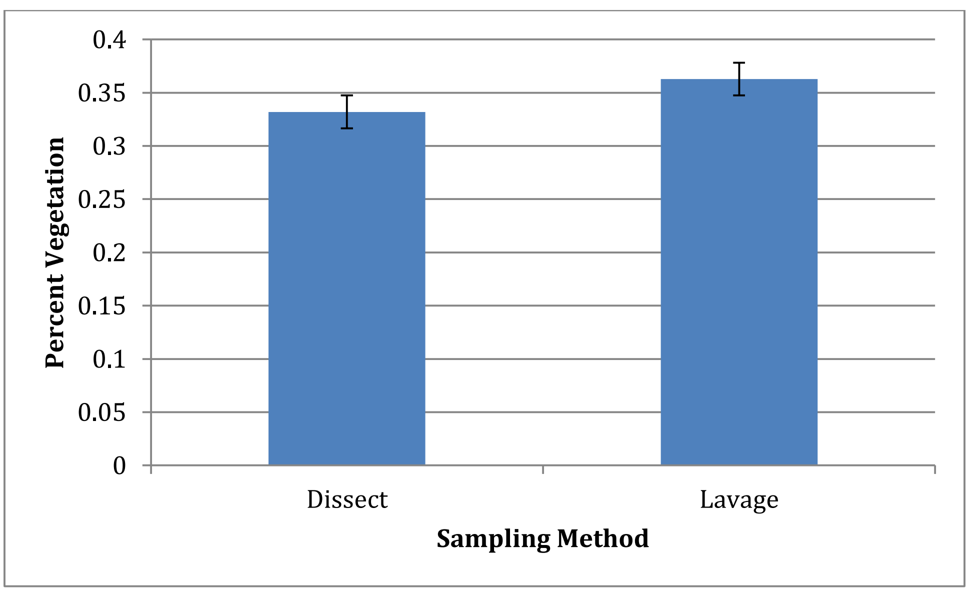

Fig. 7. Average percentage of diets made up of vegetation. Error bars represent standard error. Average percentage of vegetation was not significantly different between dissection and lavage methods (p>0.05).

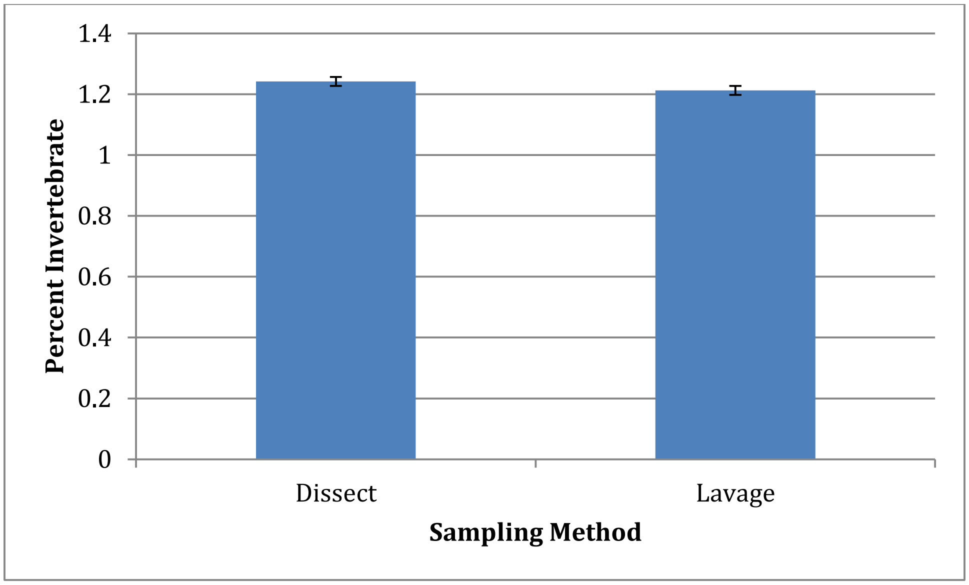

Fig. 8. Average percentage of diets made up of invertebrates. Error bars represent standard error. Average percentage of invertebrates was not significantly different between dissection and lavage methods ($p>0.05$).