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COMPARING TROPHIC LEVEL POSITION OF INVERTEBRATES IN FISH AND FISHLESS LAKES IN ARCTIC ALASKA

by

Katie Fisher

Thesis submitted in partial fulfillment of the requirements for the degree

of

HONORS IN UNIVERSITY STUDIES WITH DEPARTMENTAL HONORS

in

Watershed and Earth Systems in the Department of Watershed Science

Approved:

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Abstract

Comparing Trophic Level Position of Invertebrates In Fish And Fishless Lakes In Arctic Alaska

By Katie Fisher

Arctic lakes are likely very sensitive to the effects of climate change. Thus it is important to understand the current food web dynamics and energy flow within these lakes, to better understand how they will change in the future due to the effects of a rapidly changing climate. In order to contribute to this understanding, my project consists of an analysis of stable isotopes of carbon (delta 13 C) and nitrogen (delta 15 N) from invertebrates among fish and fishless lakes in arctic Alaska, to compare their trophic level positions and primary energetic sources. I collected pelagic invertebrates from 5 different lakes, 2 of which have resident fish populations and 3 of which are fishless. I analyzed and compared the stable isotope results with isotopic data collected from other related projects and one additional fish-inhabited lake. With this analysis, I created food webs to: 1) assign trophic positions to each species in each lake and compare those positions across lakes; and 2) assess the potential effect fish predation has on pelagic invertebrate community structure. I hypothesized that fish predation will determine zooplankton community structure and alter trophic linkages. This was proven to be true in the case of one fishless lake, whose predacious zooplankton's trophic position was the same as the fish in the other lakes. However, for the two other fishless lakes, the trophic position of the predacious and herbivorous zooplankton decreased. The decrease was possibly due to much smaller sizes of the fishless lake, or the unexamined presence of another predatory invertebrate..

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Introduction

The foundation of trophic levels initially evolved from research on terrestrial systems (Hairston et al., 1960), but there have been many applications within aquatic systems. A trophic level is simply the placement and categorization of a species in a food web based system. This placement can be based on many factors; most recently, many ecologists use ratios of stable isotope nitrogen ($\delta^{15}N$; Pasquaud et al., 2010). Energy transfer through isotopes is comprised of the source of energy, determined from ratio of stable isotope carbon ($\delta^{13}C$), and the fate of energy, determined from $\delta^{15}N$ (Peterson and Fry, 1987). In lake studies, stable isotopes have been used to assign trophic level positions of organisms and to assess the flow of energy throughout a lake food web, both of which give important context for how the ecosystem is structured.

Trophic positions can provide information about the type of trophic control in a system. Food webs are usually divided—top-to-bottom or bottom-to-top, depending on which organisms have the most influence on a system—into primary producers, decomposers, primary consumers, secondary consumers, and tertiary consumers (Hairston et al., 1960). These trophic levels can be further organized into more precise sublevels. Predators, such as fish, can influence herbivore trophic positions by modifying food sources, competitors, and habitat use—an effect sometimes referred to as trophic cascade (Pace, 2013; Vander Zanden & Rasmussen, 1999). Trophic levels are often used to determine predator-prey relationships and pathways of energy transfer within a lake ecosystem (Pasquad et al., 2010; Zhang et al., 2012).

Arctic lakes are typically oligotrophic, or nutrient-poor (Whalen and Cornwell, 1985) with relatively simple food (McDonald et al., 1996) and thus are expected to be particularly sensitive to disturbance (Shaver et al., 2010). Arctic ecosystems are expected to warm by 3-6 °C

during the next 50 years, which could have significant impacts on food availability and fishes within arctic lakes (McDonald et al., 1996). My study will aid in further understanding such sensitive limnetic ecosystems by documenting the role of predators in structuring food webs. Differences in trophic position of pelagic consumers have been used to assess how fish affect trophic position of secondary trophic level taxa and lower energetic pathways (e.g., a change in the trophic level of pelagic predators in the absence of fish). In this study, I determined the trophic levels of individual species of pelagic invertebrates using an analysis of the stable isotopes of nitrogen and carbon in their tissue (Schmidt et al., 2007). I then compared the trophic position of individual taxa present in both fish-inhabited and fishless lakes.

Methods

I collected pelagic invertebrates in 2011 and 2012 from 5 different lakes and ponds, 2 of which have resident fish populations and 3 of which are fishless (Fig. 1). Some of the data from these lakes, and the additional fish-inhabited lake, Fog 2, were supplemented by previous isotopic analysis from the Utah State University, Ecology Fishery Lab, collected between 2001 and 2008. My study lakes vary widely in surface area from <0.5 ha to 150.0 ha (Table 1). The maximum depth of my study lakes

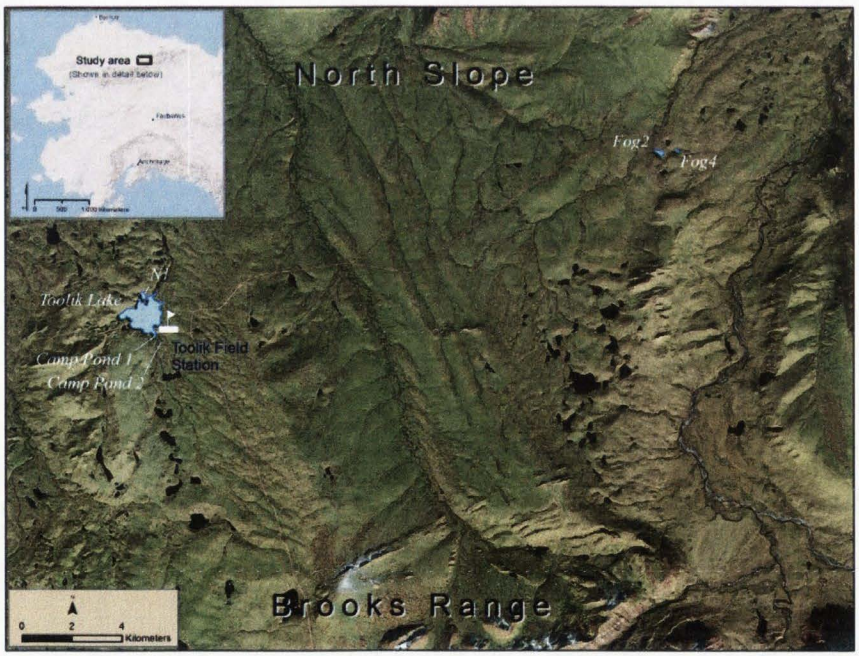


Figure 1 Study sites, 6 lakes located near Toolik Field Station in Northern, arctic Alaska

also vary widely from <3.0 m to 26.0 m (Table 1). These sites are located near Toolik Lake Field Station in northern Alaska (Fig. 1).

Lake	Maximum Depth (m)	Surface area (ha)	Fish present
Fog 2	20.3	5.65	Y
N1	14	4.4	Y
Toolik	26	150	Y
Fog 4	5.4	1.89	N
Camp Pond 1	<3	<.5	N
Camp Pond 2	<3	<.5	N

Table 1 Lake characteristics of study sites

The invertebrates were collected by conducting a tow of either a vertical or horizontal zooplankton net (Fig. 2), depending on the size and depth of the lake. Two types of invertebrates were sampled for this study: pelagic predacious zooplankton heterocope and pelagic herbivorous zooplankton *Daphnia middendorf.* Between 2011 and 2012, at least 3 replicates of each type were submitted to be read by mass spectrometer for analysis of stable isotope composition at the University of California Davis Stable Isotope Facility in 2011 and Washington State University Stable Isotopic Core Lab in 2012. The mass spectrometer results from both laboratories yielded isotopic signatures for C and N using this equation (1):

$$\delta^{13}\mathrm{C} \text{ or } \delta^{15}\mathrm{N} = \left[\left(\frac{\mathrm{R}_{sample}}{\mathrm{R}_{standard}}\right) - 1\right] \times 1000$$

where, R is the ratio between $^{13}C/^{12}C$ or $^{15}N/^{14}N$, found for both the sample and a standard. Averages of these raw values of $\delta^{13}C$ and $\delta^{15}N$ were then plotted in a scatter plot graph, with $\delta^{13}C$ in the x-axis and $\delta^{15}N$ in the y-axis with error bars (1 standard error).

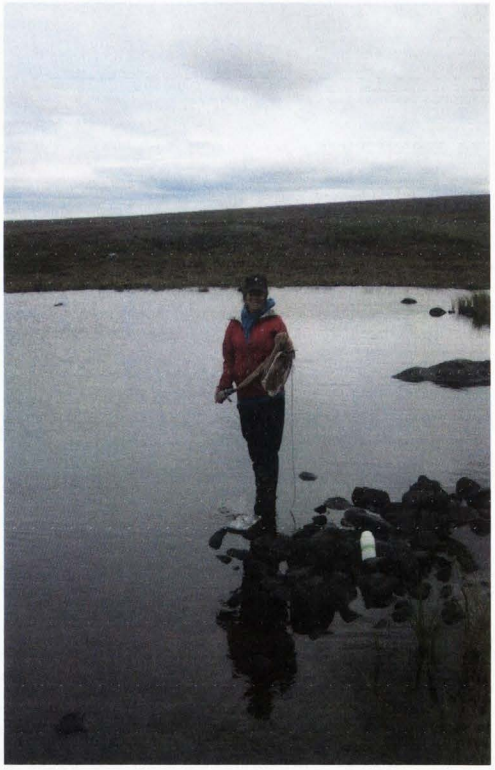


Figure 2 Katie Fisher sampling for zooplankton

Isotope data was also contributed from previous years, to increase the sample size and diversity. The nitrogen

signatures were corrected as (Olsson et al., 2009) (2):

$$\delta^{15}N_{corrected} = \delta^{15}N_i - \left(\overline{\delta^{15}N_i} - \overline{\delta^{15}N_m}\right)$$

where, $\delta^{15}N_i$ is the nitrogen signature of each individual species *i*, $\overline{\delta^{15}N_i}$ is the mean nitrogen signature of study site *i*, and $\overline{\delta^{15}N_m}$ is the minimum mean nitrogen signature of all the study sites. The corrected values were used to calculate the trophic position of the invertebrate species within each lake as (Layman et al., 2007) (3):

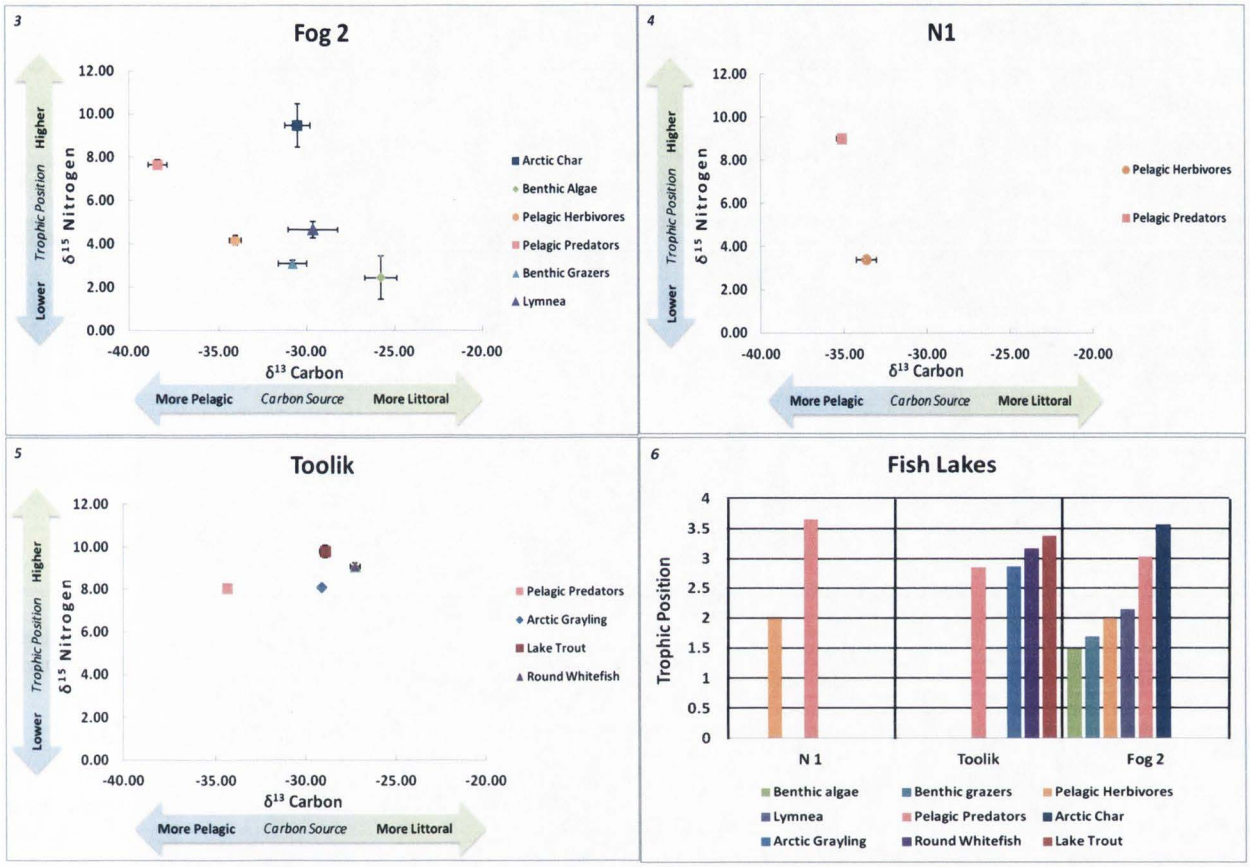
$$TP_i = \frac{\delta^{15}\mathrm{Ncor_i} - \delta^{15}\mathrm{Ncor_{cf}}}{3.4} + 2$$

where, $\delta^{15}\mathrm{Ncor_i}$ is the corrected nitrogen signature of species, *i*, and $\delta^{15}\mathrm{Ncor_{cf}}$ is the corrected nitrogen signature of the collector filterer species (the lowest, or base, of the trophic levels), (Vander Zanden & Rasmussen, 1999) with 3.4 as the trophic fractionation of trophic level increase, and with the 2 added on to be the trophic position assigned to the collector filterers.

Results

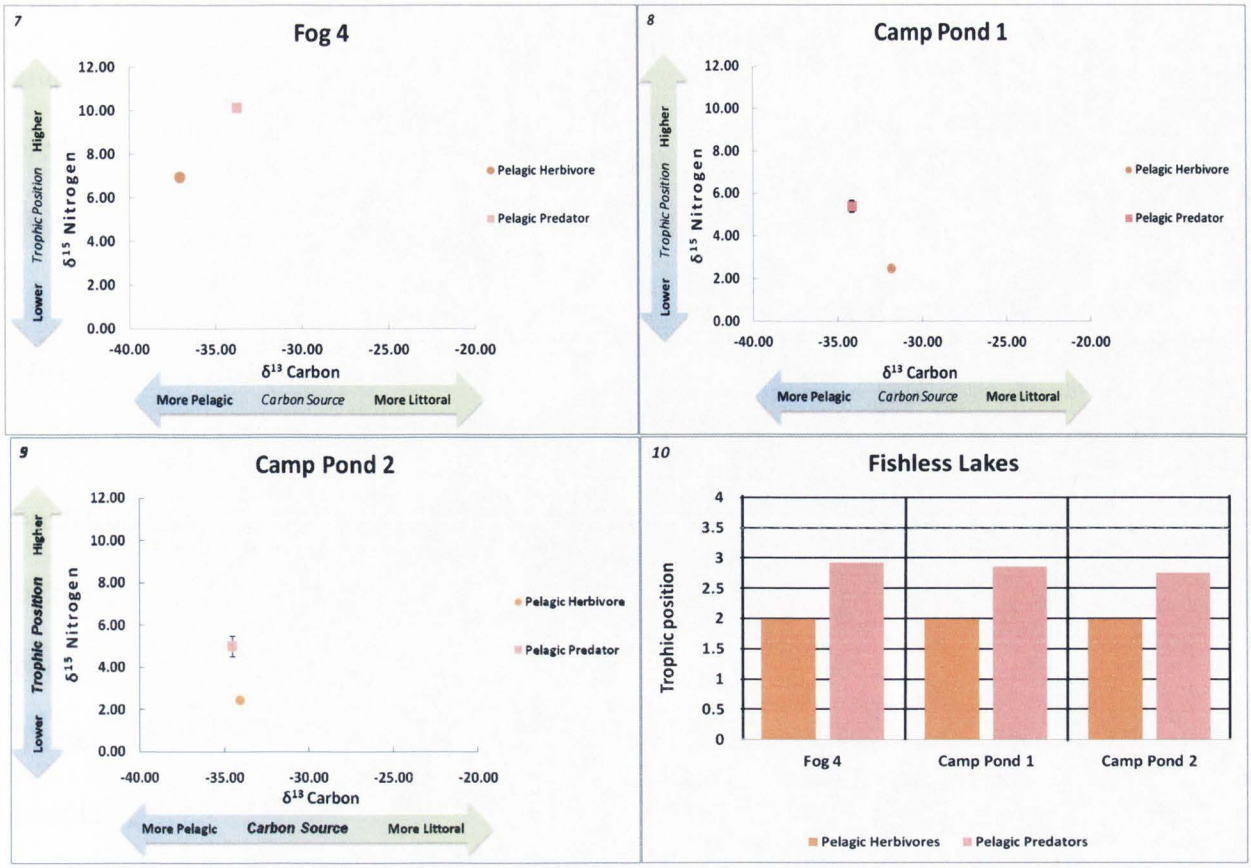
Generally, there was not a large difference between the $\delta^{13}C$ values for pelagic, herbivorous zooplankton in fish-inhabited lakes. The $\delta^{13}C$ values for pelagic, herbivorous zooplankton in fish-inhabited lakes were -34.06 for Fog 2 (Fig. 3), -33.64 for N1 (Fig. 4). Isotope data for herbivorous zooplankton were not available for Toolik Lake. The $\delta^{13}C$ values for pelagic, predacious zooplankton in fish-inhabited lakes were slightly lower than pelagic, herbivorous zooplankton at -34.41 for Fog 2 (Fig. 3), -35.13 for N1 (Fig. 4), and -34.33 for Toolik (Fig. 5). The $\delta^{15}N$ values for predators in the fish-inhabited lakes were high, at 7.64 for Fog 2 (Fig. 3), 9.0 for N1 (Fig. 4), and 8.02 for Toolik (Fig. 5). The $\delta^{15}N$ values for herbivores in the fish-inhabited lakes were much lower than the predators, being at 4.15 for Fog 2 (Fig. 3)

and 3.39 for N1 (Fig. 4). Isotope data for herbivorous zooplankton were not available for Toolik Lake. The corrected values for $\delta^{15}N$, used to graph the trophic positions of pelagic, predacious zooplankton in the fish-inhabited lakes were similar with the exception of N1 (Fig. 6) and were identical in the case of pelagic herbivorous zooplankton.



Figures 3-5 are raw $\delta^{13}C$ and $\delta^{15}N$ values to indicate trophic position and source of carbon for organisms within the lakes. Figure 6 shows the trophic position, using corrected $\delta^{15}N$ values, for organisms within the lakes.

Isotopic data for fish within the fish-inhabited lakes Fog 2 and Toolik demonstrate that fish have high $\delta^{15}N$ and high $\delta^{13}C$ values: for Fog 2, arctic char had a $\delta^{15}N$ of 9.46 and a $\delta^{13}C$ value of -30.50 (Fig. 3); for Toolik, arctic grayling had a $\delta^{15}N$ value of 8.08 and a $\delta^{13}C$ value of -29.09, lake trout had a $\delta^{15}N$ value of 9.78 and a $\delta^{13}C$ value of -28.90, and round whitefish had a $\delta^{15}N$ value of 9.10 and a $\delta^{13}C$ value of -27.24 (Fig. 5). No fish isotopic data were available for N1.



Figures 7-9 are raw $\delta^{13}C$ and $\delta^{15}N$ values to indicate trophic position and source of carbon for organisms within the lakes. Figure 10 shows the trophic position of, using corrected $\delta^{15}N$ values, for organisms within the lakes.

Compared to the fish-inhabited lakes, the $\delta^{13}C$ value for pelagic, herbivorous zooplankton was very low at -37.05 for fishless lake Fog 4 (Fig. 7). I observed higher values of -31.85 for Camp Pond 1 and -34.07 for Camp Pond 2 (Figs. 8, 9). The $\delta^{13}C$ values for pelagic, predacious zooplankton in fishless lakes were higher than pelagic, herbivorous zooplankton in Fog 4, at -33.72 (Fig. 7). The $\delta^{13}C$ values for pelagic predacious zooplankton in fishless lakes were lower than the herbivores at values of -34.18 for Camp Pond 1 and -34.53 for Camp Pond 2 (Figs. 8, 9). The $\delta^{15}N$ value for pelagic herbivorous zooplankton in fishless Fog 4 was higher than in fish-inhabited lakes (6.94; Fig. 7). The $\delta^{15}N$ values were lower for Camp Pond 1 and Camp Pond 2, at very similar values of 2.47 and 2.44 (Figs. 8, 9). The $\delta^{15}N$ value for predators in fishless Fog 4 is higher than in fish-inhabited lakes, at 10.11 (Fig. 7). The $\delta^{15}N$ values for fishless Camp

Pond 1 and Camp Pond 2 were much lower at 5.39 and 5.01 (Figs. 8, 9). The trophic positions, graphed with the corrected values for $\delta^{15}N$, in fishless lakes were very similar for all the pelagic, predacious zooplankton and very similar for all of the pelagic, herbivorous zooplankton (Fig. 10).

Discussion

In comparing Fog 4 to the fish-inhabited lakes, it appears that, as hypothesized, fish predation has an effect upon lower trophic level predators and herbivores. The raw $\delta^{15}N$ values of pelagic predacious zooplankton in Fog 4 indicate that, in the absence of fish predation, they occupied the same trophic niche as arctic char in Fog 2 and round whitefish in Toolik. Therefore, the presence of fish can lower the trophic position of predacious and herbivorous zooplankton, and conversely the absence of fish can increase the trophic position.

Contrary to my original hypothesis, the lack of fish predation in Camp Pond 1 and Camp Pond 2 yielded lower trophic positions (raw $\delta^{15}N$ values), rather than raising them, as observed in Fog 4. However, the corrected trophic positions for these predators were similar to the predacious zooplankton in fish-inhabited lakes.

Additionally, a general trend was observed for pelagic, predacious zooplankton, in both fish and fishless lakes. These zooplankton appeared to have distinguishable sources of carbon that were more pelagic than littoral, relative to the herbivorous zooplankton (although both zooplankton appear to have pelagic carbon sources). The only exception to this pattern was observed in Fog 4, where the herbivorous zooplankton appear to have a more pelagic source of carbon than the predacious zooplankton.

The small sample size of 6 lakes with supplemental fish data allowed for basic zooplankton collection methods, inexpensive isotopic analysis, and simple comparisons among lakes. However, one limitation of the study is that the 6 lakes had extremely different sizes and may have occupied different geologies, which may have contributed greatly to variation within the results. For example, the lower, raw $\delta^{15}N$ values and differences in $\delta^{13}C$ values in Camp Pond 1 and Camp Pond 2 may have been caused by the much smaller size of those two lakes than Fog 4. The influence of lake size on the food web here would be consistent with findings in Hershey et al. (2006), which found that zooplankton in small, oligotrophic lakes consume more allochthonous sources of carbon and small amounts of $\delta^{15}N$ in their food. Furthermore, the likely significant presence of the voracious, predatory *chaoborus* (sp.) has been documented in arctic, freshwater ponds (Dupuis et al., 2008), was not considered in this study (they are extremely difficult to collect).

Another potential limitation of the study was that only one species of herbivorous zooplankton and one species of predacious zooplankton was collected from each lake. This low diversity made the basal corrections of $\delta^{15}N$ too simplistic and basal corrections of $\delta^{13}C$ impossible. In contrast, much more comprehensive species composition existed in the supplementary data. When the $\delta^{15}N$ values were corrected for basal resources, the predacious zooplankton in fishless lakes occupied the same trophic level as those in fish-inhabited lakes, with the exception of N1. Additionally, due to lack of data on the lowest trophic positions (e.g., phytoplankton), basal corrections on $\delta^{13}C$ were not possible. Perhaps with more thoroughly y corrected basal values of $\delta^{15}N$ and $\delta^{13}C$, fish predation would have appeared to have more of an effect on the differences in trophic levels than the raw data shows.

Conclusion

Overall, my study demonstrates that isotopic signatures within pelagic invertebrates vary greatly among individual lakes, contributing to a complexity among food webs. The initial differences in trophic levels I observed between fish and fishless lakes were most likely due to species composition and/or the presence or absence of predacious fish. In the case of fishless lake Fog 4, pelagic, predacious zooplankton occupied a trophic level similar to that of fish-inhabited lakes. Although this shift demonstrates the potential affect of fish on the trophic levels of lower-level predators, the same shift was not observed in the other two fishless lakes, Camp Pond 1 and Camp Pond 2. The lack in trophic level shift of these two fishless lakes is possibly due to the effect of lake size and species composition, the influence of which could be determined in further studies. Understanding the biotic communities of these vulnerable, lentic systems on an individual (lake-wide) basis is critical, as different types of systems (e.g., fish vs. fishless, deep vs. shallow) may respond differently to climate change.

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Biography

Katie Fisher, raised in Centerville, Utah, graduated in 2009 from Viewmont High School. She entered Utah State University in the Fall of 2009 as a Watershed and Earth Systems Major. As an incoming freshman, she was awarded the Quinney Scholarship from the College of Natural Resources and the Dean's Scholarship from the University. Beginning in both USU's Honors Program and Research Fellowship, Katie became very engaged in research opportunities through work, Honor's contracts, and an undergraduate research project. After she graduates in May 2013, Katie plans on taking a year off from school, which entails working a summer in arctic Alaska, getting married, and applying for graduate school.