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Effects of Water Temperature on Fish Distribution in the Swannanoa River Watershed

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Abstract

Current relationships between fish distributions and temperature can be accurate predictors of future distributions resulting from climate change. This study quantified the current temperatures of Swannanoa River tributaries and used this data to evaluate the effects of temperature on fish distribution. The distribution of seven species of fish was compared across six tributaries in the Swannanoa with a representative range of water temperatures. Tributaries were then categorized as being either cool or warm water habitats. Mottled sculpin was found to be more prevalent in cooler water, while northern hogsuckers, river chubs, warpaint shiners, blacknose dace, and central stonerollers, were found to be more prevalent in warmer streams. The results of the study suggest that temperature plays a significant role in fish habitat selection. These results could be used to estimate future fish distributions, and to identify species at risk of extinction if global increases in average temperature continue.

1. Introduction

Previous studies have shown that relationships between fish distributions and temperature can be accurate predictors of future distributions resulting from climate changes.[2] It is important to be aware of current fish distributions based on temperature so that scientists and policymakers can predict future distributions of fish in the area.[9] Having this knowledge allows for more informed conservation and management efforts to take place, which is especially important given the sensitive nature of freshwater ecosystems.

Current declines in biodiversity are greater in freshwater ecosystems than in terrestrial ecosystems.[2] Freshwater stream and river ecosystems are more sensitive to changes in temperature than terrestrial systems due to the combined effects that temperature increases have on the dissolved oxygen contents of the streams as well as on the metabolism of fish.[4] Given the threat of climate change is causing increases in stream temperature, it can be expected that current biodiversity losses will be exacerbated in coming years, and that water quality and species distributions will change as a result of temperature increases.[9] Since freshwater ecosystems will be more greatly affected by climate change than terrestrial ecosystems, these ecosystems should be studied, so that the effects of climate change can be predicted, and management and conservation steps can be taken to help mitigate the extent of these biodiversity losses.

Streamflow and water temperature are the primary variables influencing the distribution of freshwater taxa, and climate-induced changes in these distributions are already causing shifts in species distributions,[9] particularly through the systemic movement towards higher elevation, upstream areas. [3] From these trends, it is possible to predict how fish species distributions will be affected by climate change based on the current temperatures and fish distributions in the river. Other researchers have been able to generate models through which the temperature shift from climate change in a given stream can be predicted,[6] and with temperature data related to fish distribution, this could be used to predict potential range shifts or extinctions in the region as a result of climate change. No prior research has been done on the effect that climate-induced range shifts will have on fish in the Swannanoa watershed. There also is a gap in the knowledge of the effect that temperature has on fish species that are not of commercial importance,[2] and this study will also help to expand the body of research on the effect of temperature on those species. Better information about the effects of river temperature on species distribution can therefore contribute to better fish protection and more efficient fisheries management[1] in the Swannanoa Rivershed.

The Swannanoa River Watershed is located in Buncombe County, North Carolina, and is a major tributary to the French Broad River. This study seeks to explore the extent to which fish distribution in this system is affected by water temperature and to identify the warmest and coolest feeders in the Swannanoa River watershed. This will be the first study mapping the temperature of the Swannanoa River and will fill a gap in the current body of knowledge about the temperature and distribution of fish in the Swannanoa and its feeder streams.

2. Methods

The study sites were Beetree Creek, Sweeten Creek, Camp Branch, Haw Creek, Flat Creek, and the Headwaters of the Swannanoa near Yates Avenue in Black Mountain, NC. All study sites were located within Buncombe County, NC. Data Loggers were placed in streams between May and June of 2020 and were retrieved in October of 2020. Electrofishing of streams occurred between August and September of 2020.

HOBOWare temperature data loggers were used to record tributary and river temperatures in two-hour increments at six different sites in the Swannanoa and its tributaries. At each tributary measured, a data logger was placed in the tributary near the bank of the stream, in a location with a large object such as a boulder to shield from the current in front of it where possible. Data loggers were placed in a sealed off PVC pipe structure, that had holes drilled into its sides to allow for water to pass through the tube. Tubes were spray painted brown and were covered with rocks to ensure that the data loggers were not interfered with during the experiment. One data logger was lost during the peak temperature months of July and August, and so peak and average temperature had to be estimated using the data that was collected in October. This was accomplished by comparing the difference in average temperature to its closest tributary and estimating values based on this difference.

Fish data was collected using an electrofisher. Approximately 50 meters were sampled at each site, or enough distance to sample two riffles and two pools. Fish were collected with dip nets, placed in a bucket, and identified on-site. A wide range of fish abundance was observed between sites, with as low as 32 fish being collected at some sites and as high as 87 fish being collected at others. In addition, the region of stream that was electrofished was broken down into six evenly spaced transects, where flow velocity and depth were measured in 1-meter intervals across the stream bed.

3. Results

Average stream depth ranged from 16-31 cm and average flow velocity ranged from 0.85-2.79 ft/sec. Fish species that were represented in at least 4 of the 6 sampled tributaries were used to compare the population sizes between the two groups. These species were central stonerollers (*Campostoma anomalum*), blacknose daces (*Rhinichthys atratulus*), fantail darters (*Etheostoma flabellare*), mottled sculpin (*Cottus bairdii*), northern hogsuckers (*Hypentelium nigricans*), river chubs (*Nocomis micropogon*), and warpaint shiners (*Luxilus coccogenis*) (Table 1). Due to low replication, an alpha of 0.1 was used to evaluate statistical significance. To determine whether the limiting temperature factor in streams was peak temperature or peak weekly average temperature, a linear regression was performed for all species using both metrics (Figure 1, Figure 2), and the Pearson's coefficient values were compared (Table 2). R-squared values were lower for the highest weekly average temperature for most species, so this metric was used for future calculations. After examining the average temperatures of the tributaries of interest, it became apparent that the sampled tributaries fell into two distinct temperature categories, with cold temperature streams ranging from 65-67 °F, and warm water tributaries ranging in average temperature from 70-73°F (Figure 3). For all species, the results of a t-test comparing populations of warm and cold tributaries did not produce a significant p-value at a 0.9 confidence interval (Table 3).

Table 1. Raw Data Showing Number of Each Species Captured at Each Site.

Site	**Blacknose Dace**	**Central Stoneroller**	**Fantail Darter**	**Mottled Sculpin**	**Northern Hogsucker**	**River Chub**	**Warpaint Shiner**
Beetree Creek	0	8	1	12	0	4	2
Swannanoa @Yates	5	5	0	6	0	0	0
Camp Branch	2	18	3	26	0	0	0
Haw Creek	10	2	0	0	5	20	19
Sweeten Creek	0	31	1	0	6	21	4
Flat Creek	1	0	1	7	2	8	1

Table 2. P-Values From Pearson's Coefficient Comparing Fish Abundance By Maximum Recorded Temperature And Maximum Weekly Temperature.

	Central Stoneroller	Blacknose Dace	Fantail Darter	Mottled Sculpin	Northern Hogsucker	River Chub	Warpaint Shiner
Max Temp p-value	0.306	0.637	0.511	0.643	0.664	0.637	0.411
Max Average Weekly Temp p-value	0.517	0.830	0.442	0.589	0.128	0.069*	0.206

Table 3. Fish Abundance At Warm And Cold Sites

	Central Stoneroller	Blacknose Dace	Fantail Darter	Mottled Sculpin	Northern Hogsucker	River Chub	Warpaint Shiner
Mean Cold	13.67	2.67	1.33	13	0.67	2.67	.33
Mean Warm	7.67	3.33	0.67	4	3.67	15	8.33
p-value	.5928	.8599	.5185	.3040	.2028	.1141	.2109

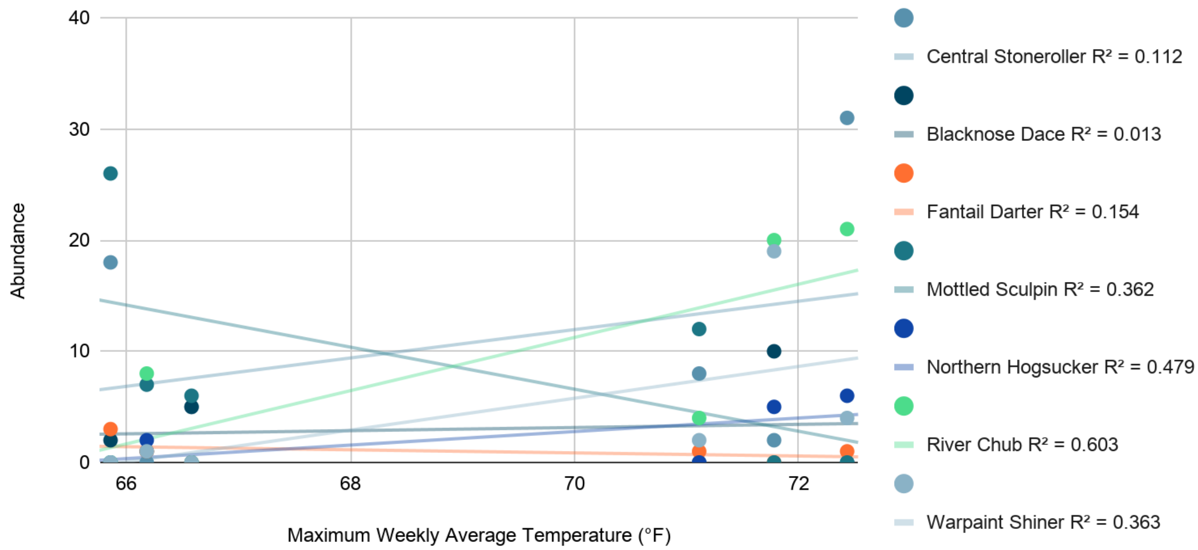

Figure 1. Fish Abundance Based On Highest Weekly Average Temperature

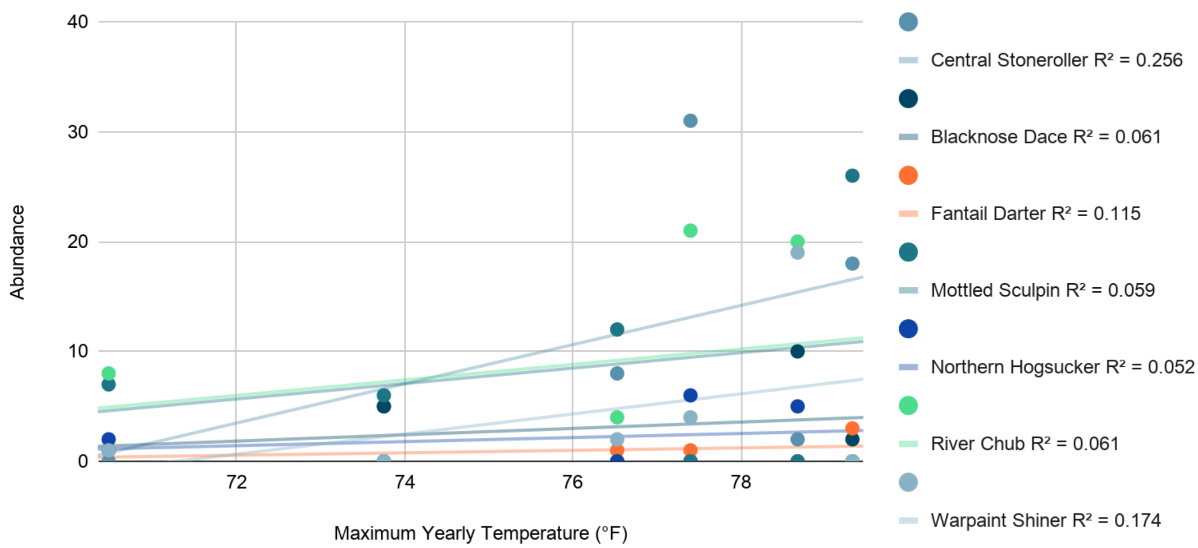

Figure 2. Fish Abundance Based On Highest Recorded Temperature

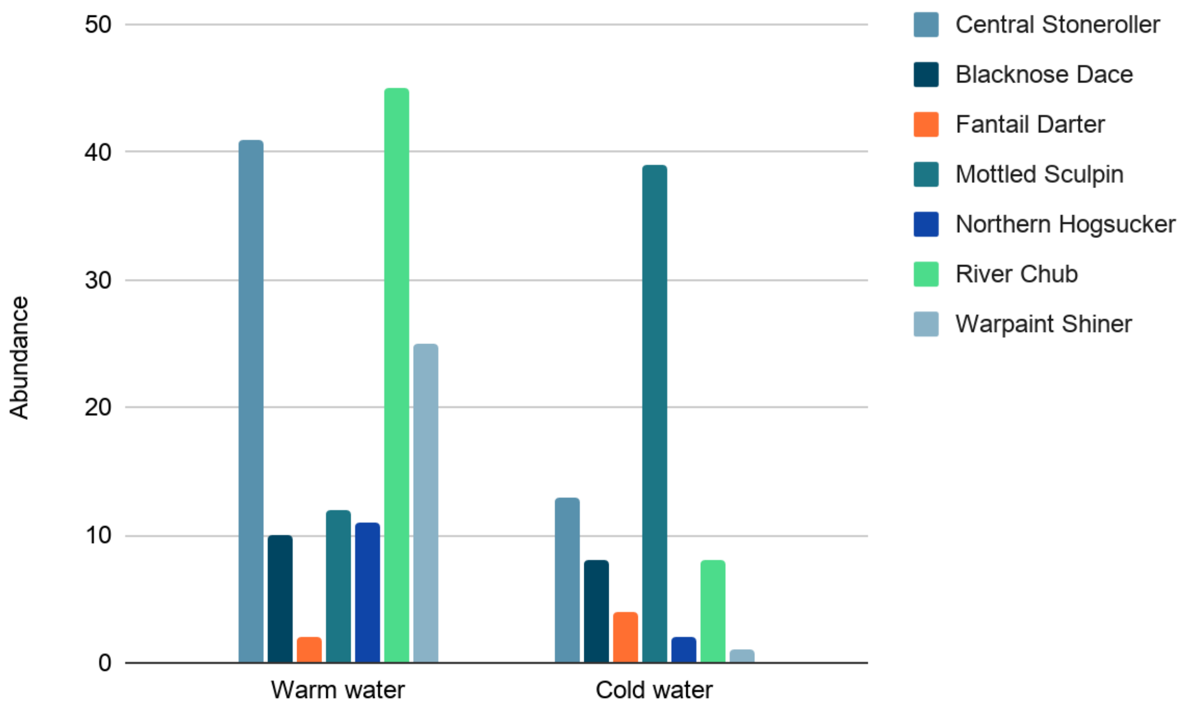

Figure 3. Fish Abundance Between Warm Water And Cold Water Tributaries

4. Discussion

The overall results did not support the hypothesis that fish abundance would be correlated with temperature in the Swannanoa Watershed. There was one instance of statistical significance in the data with river chub preferring warm water tributaries to cold water ones, but overall the results showed less significance than expected. For many species, there were notable trends in the data which were not proven to be statistically significant, particularly for mottled sculpin, a known coldwater species, whose average abundance was more than doubled in cool water habitats compared to warm water. In addition, warpaint shiners may also represent a trend of interest, as there was a very large discrepancy between the mean abundance in cold and warm waters. My findings suggest that most fish in the Swannanoa Watershed may not be as sensitive to temperature fluctuations as compared to research that has been performed in other regions. In addition, since the only fish shown to have an abundance that was significantly correlated with temperature preferred warmer habitats, this suggests that climate change may not be a major concern for freshwater fish in the area. In the future, it would be worthwhile to compare fish distribution across other metrics as well, such as depth, substrate, or dissolved oxygen content, as temperature is not the only limiting factor for fish species, and there is reason to believe that if temperature shifts do drive fish populations upstream, those fish may also be limited by other factors and be unable to survive in the upstream habitat. This concern is the biggest reason why shifts in distributions will lead to overall decreases in biodiversity, as well as the risk of cold-water preferring species simply being driven out of all available freshwater habitats entirely.

5. References

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