THE PENNSYLVANIA STATE UNIVERSITY
SCHREYER HONORS COLLEGE

DEPARTMENT OF ECOSYSTEM SCIENCE AND MANAGEMENT

THE DETERMINATION OF TEMPERATURE PREFERENCE ON THE ADULT ROUND GOBY (*Neogobius melanostomus*)

MOLLY A CARSON
SPRING 2025

A thesis
submitted in partial fulfillment
of the requirements
for a baccalaureate degree
in Wildlife and Fisheries Science
with honors in Wildlife and Fisheries Science

Reviewed and approved* by the following:

Jay Stauffer Jr.
Professor of Ichthyology
Thesis Supervisor

C. Paola Ferreri
Associate Professor of Fisheries Management
Honors Adviser

* Electronic approvals are on file.

ABSTRACT

The Determination of Temperature Preference on the Adult Round Goby (*Neogobius melanostomus)*

The Round Goby *Neogobius melanostomus* is an invasive, benthic fish species with origins tracing back to the seas of Eurasia. The Round Goby is thought to have invaded North American waters through the ballast tanks of ocean freighters in the early 1990s. Currently, the Round Goby inhabits all the Great Lakes and many of their associated tributaries, heavily predating and outcompeting native aquatic species. To effectively manage and prevent the continued spread of the Round Goby in North America, it is important to recognize their thermal tolerance range and preferred habitat temperature. To better understand how changes in water temperature influence the biological mechanisms and geographic range of the Round Goby, we used Round Gobies collected from Lake LeBoeuf by the Pennsylvania Fish and Boat Commission in August 2024 and performed multiple temperature preference trials in the fish laboratory at the Rock Springs Research Farm from September 2024 through December 2024.

Results of this study show that the Round Goby is capable of living in a wide range of water temperatures. Further analysis shows that the Goby's maximum thermal tolerance is above 25°C, but Gobies will venture into water warmer than this even though it leads to loss of equilibrium. Comparing the results of this study to the results of a past temperature studies performed by Stauffer et al. (1976) and Bucha (2024) supports the idea that the Round Goby does not have a specified preferred temperature. Further research is needed to determine how other environmental conditions such as salinity may affect Goby tolerance. This study provides critical insight into how the invasive Round Goby can prosper in foreign waters, and how changing climatic conditions may aid in the species' continued geographic spread.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

First, I would like to thank Dr. Jay Stauffer Jr., my thesis supervisor and professor. He guided me through the experimental phase of the study and supported me in constructing, revising, and editing my thesis.

I would also like to thank my thesis honors adviser and professor Dr. Paola Ferreri. Her constant support and patience with my endless questions has helped make this writing process much more bearable.

I greatly appreciate the help with this study from Andrew Bucha III. He has guided me from the beginning to the end of this study and writing process, and I do not think I would have been able to complete this thesis without him.

I also want to thank Antonios Stylianides for coming with Drew and me to LeBoeuf Lake to collect the Gobies (even though we were unsuccessful) and I am appreciative of the Pennsylvania Fish and Boat Commission for providing the Gobies used in this study.

Finally, I would like to thank my roommates Marly Lough, Mac Sullivan, and Maura Fluehr, as well as my parents Beth and Rod Carson for their constant support and for putting up with my extensive rants about fish.

Chapter 1: Introduction

The Round Goby

The Round Goby, *Neogobius melanostomus* (Figure 1) is a small, benthic fish whose origins trace back to the Caspian Sea region of Eurasia. Although the Round Goby is considered highly invasive in North American waters, it is not seen as an invasive or destructive species in its native range in the Caspian Sea. The Round Goby was first discovered by recreational fishermen in North America in the St. Clair River, Ontario in 1990 (Clark et al., 2022).

Figure 1. Photo of the Round Goby (*Neogobius melanostomus*). Reproduced with permission from The Fishes of Pennsylvania (Stauffer et al., 2016).

The Round Goby is thought to have invaded North American waters through the ballast tanks of trans-Atlantic Ocean freighters traveling from the Black Sea and the Baltic Sea (Mueller et al., 2017). Although the Round Goby initially inhabited only the Laurentian Great Lakes and their associated tributaries, its geographic range has spread significantly and rapidly (Figure 2).

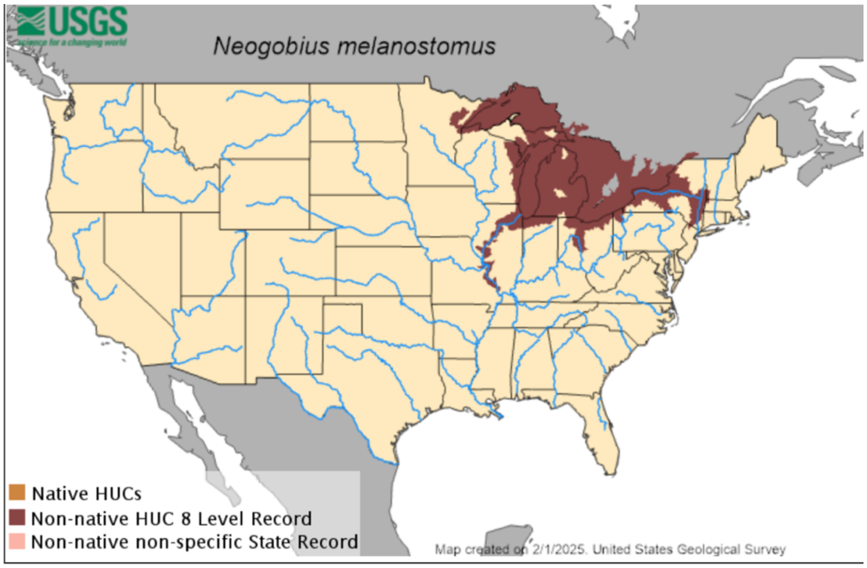

Figure 2. Map of the current distribution of Round Gobies in North America. Adapted from *Nonindigenous Aquatic Species*, United States Geological Survey (Freedman et al., 2025)

As of 2002, the Round Goby was found to have invaded numerous Pennsylvania tributaries connected to Lake Erie, including Elk Creek, Walnut Creek, Twentymile Creek, and Sixteenmile Creek (Phillips et al., 2009). By electrofishing sampling from June 2000 through October 2001, the most significant invasion was found to occur in Elk Creek, where the Round Goby made up 17.1% of the total fish population in which fish communities were found (Phillips et al., 2009). At this time, it was estimated that around 9.9 billion Round Gobies inhabited Lake Erie and its associated river systems (Johnson et. al, 2009). As of August 2014, the Pennsylvania Fish and Boat Commission released a statement that Round Gobies were found in Lake LeBoeuf and LeBoeuf Creek in Erie County near Waterford, Pennsylvania (Mueller et al., 2017).

The fish are assumed to have been unintentionally transported from Lake Erie to LeBoeuf Creek in the bait buckets of recreational anglers (Penn State, 2019). Because Round Gobies have continued to spread up the Great Lakes tributaries and have invaded various other Pennsylvania river systems due to recreational angling, their numbers are estimated to have increased significantly since the early 2000s.

Effects of Invasion

The spread of the invasive Round Goby throughout the lakes and tributaries of North America has had and will continue to have detrimental effects on native fish and aquatic macroinvertebrates. The Round Goby is a voracious feeder and has been found to prey on many native species.

More specifically, the Round Goby has been associated with the extirpation of the Mottled Sculpin *Cottus bairdi* and the decline of the Johnny Darter *Etheostoma nigrum* (Stauffer et al., 2016). Studies in Lake Michigan have shown that the invasion of the Round Goby has severely impacted the recruitment of the Mottled Sculpin and caused local populations to decline rapidly. The study confirmed that Round Gobies interfered with nest-guarding male Mottled Sculpins, seized Mottled Sculpin spawning shelters, and fed extensively on juvenile Mottled Sculpins and eggs, causing a near-total loss of the young-of-year generations (Janssen and Jude, 2001). It appears likely that these behavioral aspects of the Round Goby are also the leading cause of decline in Johnny Darter populations and recruitment in North American waters (Lauer et al., 2011).

Additionally, studies have shown that Round Gobies also prey upon mussels and have been found to contribute to the loss of indigenous unionid mussels in French Creek through direct predation (Clark et al. 2022). Moreover, the Round Goby indirectly affects mussel reproduction and recruitment by displacing and outcompeting native fish species that serve as hosts for larval mussels (Clark et al., 2022). Overall, studies have found that when Round Gobies are present, native fish, macroinvertebrates, and mussel species are heavily predated or outcompeted, causing dramatic shifts to aquatic ecosystems in North America. Finding ways to monitor and control the invasive Round Goby is crucial to keeping native environments healthy and stable.

Climate Change Effects on Freshwater Conditions in North America

Climate change and global warming have had a significant impact on a multitude of environmental conditions and ecosystems. Of all global ecosystems, the one that is most vulnerable to changes in the climate is the aquatic ecosystem. Climate change leads to increasing salinity levels, decreasing dissolved oxygen levels, and rising water temperatures, all of which pose a significant threat to a balanced species composition and the proper functioning of aquatic ecosystems both in North America and all over the world.

Because the Laurentian Great Lakes and connected tributaries provide such valuable ecosystem services to both human and fish populations in North America, the ecosystem's response to climate change has been extensively studied. According to information provided in a study conducted by Collingsworth et al. (2017), surface water temperature in the Great Lakes is estimated to increase by 2°C -7°C between 2071 and 2100. Additionally, the same study found that water temperatures below the surface are projected to be 2°C warmer throughout the water column by 2043 (Collingsworth et al., 2017).

Furthermore, a study conducted by the National Oceanic and Atmospheric Administration (2021) on the Laurentian Great Lakes found that on average, these water bodies are now covered in ice 8 to 46 days fewer than they were in the 1970s (Figure 3). This decrease in ice cover due to climate change causes dramatic changes to aquatic ecosystems, including an increase in water temperature. A decline in ice cover has also been found to increase annual evaporation in the lakes, ultimately impacting the thermally stratified water column (Mishra et al., 2011). The shift in ice cover and thermal dynamics in the Laurentian Great Lakes and associated tributary systems are bound to cause significant changes to the composition of fish communities in these water bodies, as well as allow invasive species – such as the Round Goby – that may be better adapted to changing environmental conditions to dominate previously balanced native aquatic ecosystems.

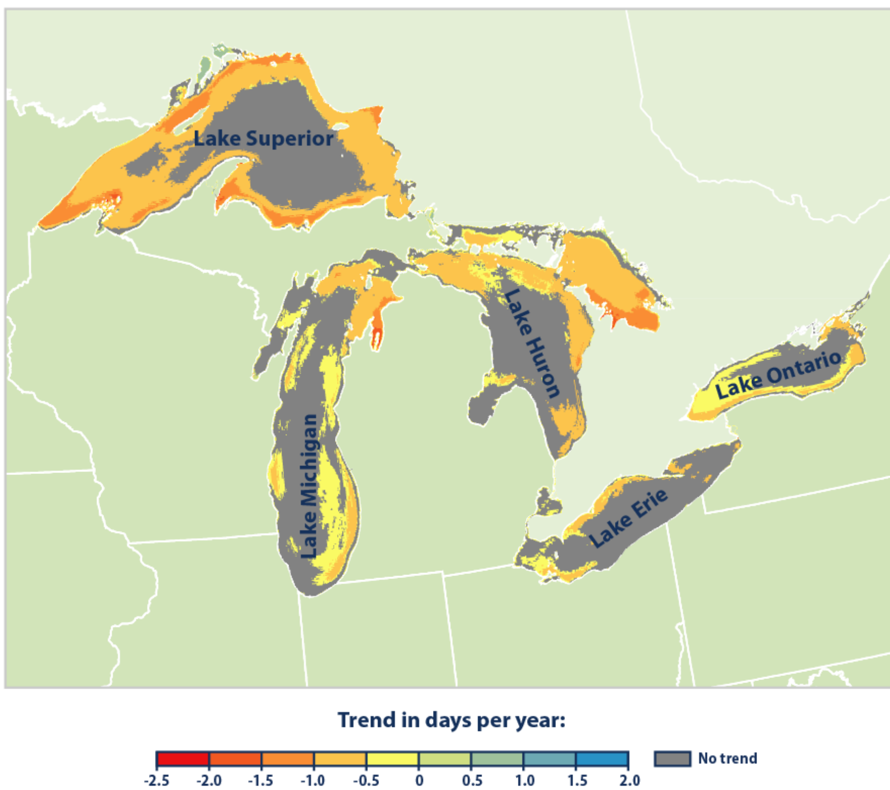

Figure 3. Map shows the annual rate of change in ice cover in the Laurentian Great Lakes from 1973-2019. The map was created by NOAA (2021) and was obtained from the United States Environmental Protection Agency (Climate Change Indicators: Great Lakes Ice Cover, 2021)

Lethal Effects of Temperature

Understanding the thermal requirements and tendencies of the Round Goby is critical for their effective management. Historically, the lethal effects of temperature on aquatic organisms were analyzed and the direct effect of temperature changes on fish mortality has been extensively studied for over 50 years. The fact that heat death is rarely observed in nature appears to contradict the fact that many organisms are killed at temperatures only slightly above those that they prefer. Death due to temperature intolerance may result from either exposure to low or high temperatures. For the most part, exposure to cold temperatures is lethal to temperate fishes only when these organisms are acclimated to elevated temperatures and abruptly exposed to lower temperatures. This phenomenon is termed “cold shock” and is usually associated with shutdowns of thermal outfalls during winter months.

In contrast, death due to exposure to high temperatures results in the ultimate breakdown in the organization of the individuals (Brett, 1956). Mayer (1914) suggests that at high temperatures, there is insufficient oxygen to sustain increased metabolic activity in many fish species. Other phenomena that result in death at high temperatures include synaptic failure (Fisher, 1958), denaturation of body cells, inactivation of cholinesterase (Kusakina, 1963), changes in enzyme systems due to high concentrations of lactic acid (Pegel and Remorov, 1961), and the failure of coordinating mechanisms of the central nervous system (Orr 1955). The failure of numerous biological systems at temperatures above 30°C was discussed by Drost-Hansen (1965), who indicated that although an organism may be alive at 33°C – 34°C, vital bodily mechanisms may be irreversibly damaged, and death will eventually occur. To support this idea, Dean and Coutant (1968) showed that 85% of juvenile Chinook Salmon who lost equilibrium because of thermal shock, died when returned to non-lethal temperatures. Gift (1970) defines critical thermal maximum as the thermal point at which locomotor activity declines and the animal loses its ability to escape from conditions that will soon cause its death. Therefore, a thermal dose that induces the loss of equilibrium for even a short period is just as detrimental as one that causes immediate death (Becker, 1973).

Invasive Species Resistance to Thermal Change

Although temperature changes have been seen to affect a diverse array of fish species, some researchers speculate that invasive species such as the Round Goby have biological or genetic mechanisms that enable them to better adapt to warming waters, owing to their continued success in the changing global climate. Zerebecki and Sorte (2011) suggest that the ability to maintain physiological function over a wide range of temperatures – defined as eurythermality – may be enhanced in invasive species. Studies show that eurythermality could be attributed to the expression of heat-shock proteins (HSPs), which assist in the refolding of denatured cellular proteins, thus reducing the cost of cellular degradation and replacement (Zerebecki and Sorte, 2011). Studies on aquatic bivalves conducted by Kelley (2014) have shown that the expression of certain HSPs was significantly higher in the invasive *Mytilus galloprovincialis* compared to the native *Mytilus trossulus*. Additionally, the invasive bivalves were found to induce HSPs at a greater maximal temperature than the native bivalves, suggesting the invasive species has a higher upper thermal tolerance (Kelley, 2014). This idea of increased heat-shock protein expression being a factor in the persistence of invasive species could be one reason why Round

Gobies have had such success in expanding their geographic range and thriving in a variety of diverse environments.

Purpose of the Study

The purpose of this experiment is to determine the final preferred temperature of the Round Goby *Neogobius melanostomus* and use this information as a surrogate for the lethal temperature of the species. Obtaining accurate data regarding the thermal tolerance of the invasive Round Goby is critical for preventing the species' further spread, thus maintaining the health and success of native aquatic species in the process. Similar studies conducted by Stauffer et al. (1976) found that certain species tended to stay in waters similar to their acclimation temperatures, with a trend of a larger percentage of individuals preferring to remain close to their acclimation temperature when the temperature is higher. We predict that the thermal preference of Round Gobies will differ significantly depending on what acclimation temperature the fish are initially exposed to. Additionally, we hypothesize that the Round Gobies will follow a similar trend to that of the species studied by Stauffer et al. (1976), with the Gobies' average preferred temperature range being narrower at the higher acclimation temperatures.

Chapter 2: Methods

Collection Process

45 adult Round Gobies were collected from LeBoeuf Lake in Erie County, Pennsylvania in August 2024. All fish were collected by benthic trawling conducted by the Pennsylvania Fish and Boat Commission. The use of Round Gobies in this study followed the methods approved by the Institutional Animal Care and Use Committee (IACUC) at The Pennsylvania State University (IACUC PROTO202302366).

Laboratory Setup

After collection, all fish were transported to Rock Springs Fish Laboratory, which is a part of the Russell E. Larson Agricultural Research Center in State College, Pennsylvania. When the Round Gobies were first brought to the Rock Springs Fish Laboratory, they were held at their original collection temperature of 15°C. The Gobies were then randomly sorted into four different acclimation tanks: 10°, 15°, 20°, and 25°C (Figure 4) for a total of 10-12 Gobies in each tank. All Gobies in these tanks were held in freshwater (<0.05 ppt salinity). One week before each trial was set to run, the temperature in these tanks was brought up or down by 2°C each day until they reached the respective acclimation levels. Once reaching these acclimation levels, the temperature in the tanks was held constant for one week (until the start of each experiment).

Figure 4. Image of aquarium tanks used to house the Round Gobies in Rock Springs Fish Laboratory, State College, Pennsylvania.

Temperature preference trials were conducted in a trough (3.6 m x 0.203 m x 0.245 m) modeled after the experiment performed by Stauffer et al. (1976). The interior of the temperature trough is painted with nontoxic epoxy paint to prevent extraneous stress or harm to the fish. The exterior bottom of the tank is coated with a temperature-resistant, matte black paint to facilitate heating from the thermistors positioned under the trough. Cool water is introduced at one end of the trough, thus creating a temperature gradient that can range above and below the acclimation temperature specified for each of the five experimental trials. The temperature ranges vary slightly among the same-temperature trials, as seen in Table 1. However, it was determined that there was not enough variation in the ranges to significantly affect the results of the trials. The temperature range of the trough was determined by the initial acclimation temperature for each trial. It is important to note that we were unable to achieve a complete temperature range for the lowest acclimation trial of 5°C. The trough temperature was unable to drop below around 7°C, so this value was determined to be the minimum temperature of the ranges for the 5°C acclimation trials.

Table 1. Acclimation trial and temperature range of the thermistors in the temperature trough. All temperatures are recorded in Celsius.

Acclimation Trial (Celsius)	Temperature Range (Celsius)
5	7.2-15.9
5	7.3-15.3
5	7.4-15.8
5	7.4-15.0
5	7.6-14.8
5	7.6-15.9
5	7.8-15.1
5	7.8-15.8
10	10.0-18.3
10	9.8-18.5
10	9.7-18.8
10	9.9-19.2
10	9.8-18.6
10	10.0-17.6
10	9.9-18.0
10	9.8-18.9
15	13.5-23.3

15	13.1-22.7
15	14.2-23.0
15	14.1-23.0
15	13.9-22.7
15	13.6-23.0
15	13.5-23.0
15	13.4-22.9
20	18.8-26.3
20	18.8-26.6
20	18.8-26.9
20	18.6- 27.2
20	18.7-27.2
20	18.7-27.3
20	18.8-27.4
20	19.0-27.4
25	24.0-30.4
25	23.8-30.7
25	23.9-30.8
25	23-30.7
25	23.8-31
25	24-31
25	24-31.3
25	24-31.5

Overhead vita-lites illuminate the test area. The sides of the trough are enclosed but latch together so that if a panel is unhooked, the inside of the trough can be easily accessed. Twelve thermistors are used to create the thermal gradient and determine the selected temperature throughout the trough (Figure 5).

Figure 5. Photo of the temperature trough and thermistor set up at Rock Springs Fish Laboratory, State College, Pennsylvania. Image obtained from Andrew Bucha III, Penn State University Master's student.

Experimental Methods

Eight fish are observed individually at each acclimation temperature: 10°, 15°, 20° and 25°C. At the beginning of the experiment, fish were transferred from the aquarium tank to a bucket using an aquarium fish net. The bucket was filled with water from the aquarium tank so no orientation period in the bucket was necessary. Individual fish were then introduced to the trough from the bucket using the same aquarium fish net. The fish was then placed in the middle of the trough. Each fish was given a 20-minute orientation period. Once the fish were inside the trough, they could turn around and swim freely during the entire orientation period and preference trial. During the orientation period in the trough, fish were periodically checked to ensure they did not squeeze behind the netting on the drain end of the trough. If they did, the aquarium net was used to gently prod the fish until it swam back toward the middle of the trough. Following the orientation period, the temperature and thermistor at which the fish is located are recorded on an Excel sheet every 20 seconds for a total of 10 minutes. The location of the fish within the trough was monitored using overhead mirrors placed above the entire length of the trough. Thermistors placed on the outside of the trough displayed the temperature in Celsius, and the thermistors were labeled 1-12 on the inside of the trough so the thermistor at which the fish was located throughout the trial could be constantly identified. After each trial was conducted, the temperature recorded every 20 seconds for 10 minutes was used to determine the preferred temperatures of the fish during their individual trials. To obtain the preferred temperature of the Round Goby during their individual trials, the temperatures recorded every 20 seconds during the 10-minute trial period were added up and divided by 30 (the number of temperatures recorded during each trial). This calculated value was deemed to be the average temperature that the fish preferred during the trial period. These preferred temperatures were then used in the statistical regression analysis described below. All 8 fish for each acclimation temperature were observed on the same day, but each preference trial took place on different days for a total of 5 separate days of experimental trials. We initially planned on performing only 4 temperature trials: 10°, 15°, 20°, and 25°C. As the study was being conducted, we decided it would be best to add a 5°C trial, so we reacclimated gobies from the 10° C trial to use again. If fish were seen to exhibit a complete loss of equilibrium, they were removed from the trial. We defined loss of equilibrium as the “inability to correct (upright) oneself after being poked with a probe”. Fish that needed to be removed from a trial due to complete loss of equilibrium were euthanized in a freshwater and clove oil mixture compliant with IACUC protocol. We euthanized these fish immediately because it was unlikely that individuals who lost equilibrium would recover, and we wanted to eliminate any unnecessary suffering. All remaining fish that were used in this study were returned to the laboratory aquarium tanks. These fish were not used in any further experiments, and once all trials were completed, all individuals were euthanized in the freshwater and clove oil mixture prescribed by IACUC.

Past Temperature Preference Study Methods

The past temperature preference models (Figures 8-10) below were created using data provided by the wildlife monographs presented by Stauffer et al. (1976). One predator species – the Rock Bass – and two prey species – the Fathead Minnow and the Bluntnose Minnow – were selected to compare the temperature preferences of each species from this past study to the temperature preference of the Round Goby. Additionally, data on the Chesapeake Logperch provided by Bucha (2024) was used to create an additional comparative temperature preference model (Figure 11). All past temperature preference graphs were created using Excel. It is important to compare the Round Goby temperature preference results to the results of past temperature studies of native North American species because it may provide crucial insight into how the Round Goby has been so successful as an invasive species.

Statistical Methods

To evaluate the temperature preferences and tolerances of the Round Goby, a statistical analysis was conducted to understand how changes in water temperature may affect survival rates and the invasive spread in North America. The statistical analysis involved plugging the data into SAS, a statistical software commonly used for data management, advanced analytics, and multivariate analysis. In SAS, we fitted the data with the REG procedure, a general-purpose procedure that fits least-squares estimates to linear regression models. The output of this procedure is a regression model comparing the acclimation temperatures and the preference temperatures from the Round Goby study. In the graph, the preference temperature represents the dependent variable. The REG procedure also provided an ANOVA table, R^2 values, and parameter estimates for the Goby data. After obtaining the graph and these values, we plugged the acclimation-preference graph into R to refine the graph and make it more presentable.

Chapter 3: Results

Round Goby Study Results

When the Round Gobies were initially placed into the trough, they tended to swim the full length of the trough for the first few minutes of the orientation period before eventually settling down into a spot. Although fish behavior differed among individuals, the general pattern of behavior showed that once fish settled into a spot in the trough, they tended to stay there for the entire orientation period and temperature trial.

The range of average preference temperatures notably differs between acclimation trials (Fig. 6). According to Figure 6, the range of average preference temperatures is greatest for the 15°C acclimation trial. For this trial, the average preferred temperature ranges from 13.1°C to 22.8°C for a range of 9.7°C (Figure 6). In contrast, the trial with the smallest range in preference temperature is the 25°C acclimation group (Figure 6). In this trial, preferred temperatures range from 26.2°C to 29.1°C for a range of 2.9°C (Figure 6). Additionally, Figure 6 suggests that the average preferred temperatures for all five trials remain within the 95% prediction limits, however, one average preferred temperature point (15.0°C) for the 5°C trial falls right on the upper prediction limit. Another important aspect to note in this model is that most of the preferred temperatures for the middle three trials (10°C, 15°C, and 20°C) fall outside of the 95% confidence limits (Figure 6). However, the majority of the average preference temperatures for the two extreme acclimation trials (5°C and 25°C) fall within the 95% confidence limits (Figure 6). Finally, it should be noted that the range of the 95% confidence limits in Figure 6 is larger towards the extreme trials – 5°C and 25°C – and narrow as they approach the 15°C trial, where the confidence limit is the smallest.

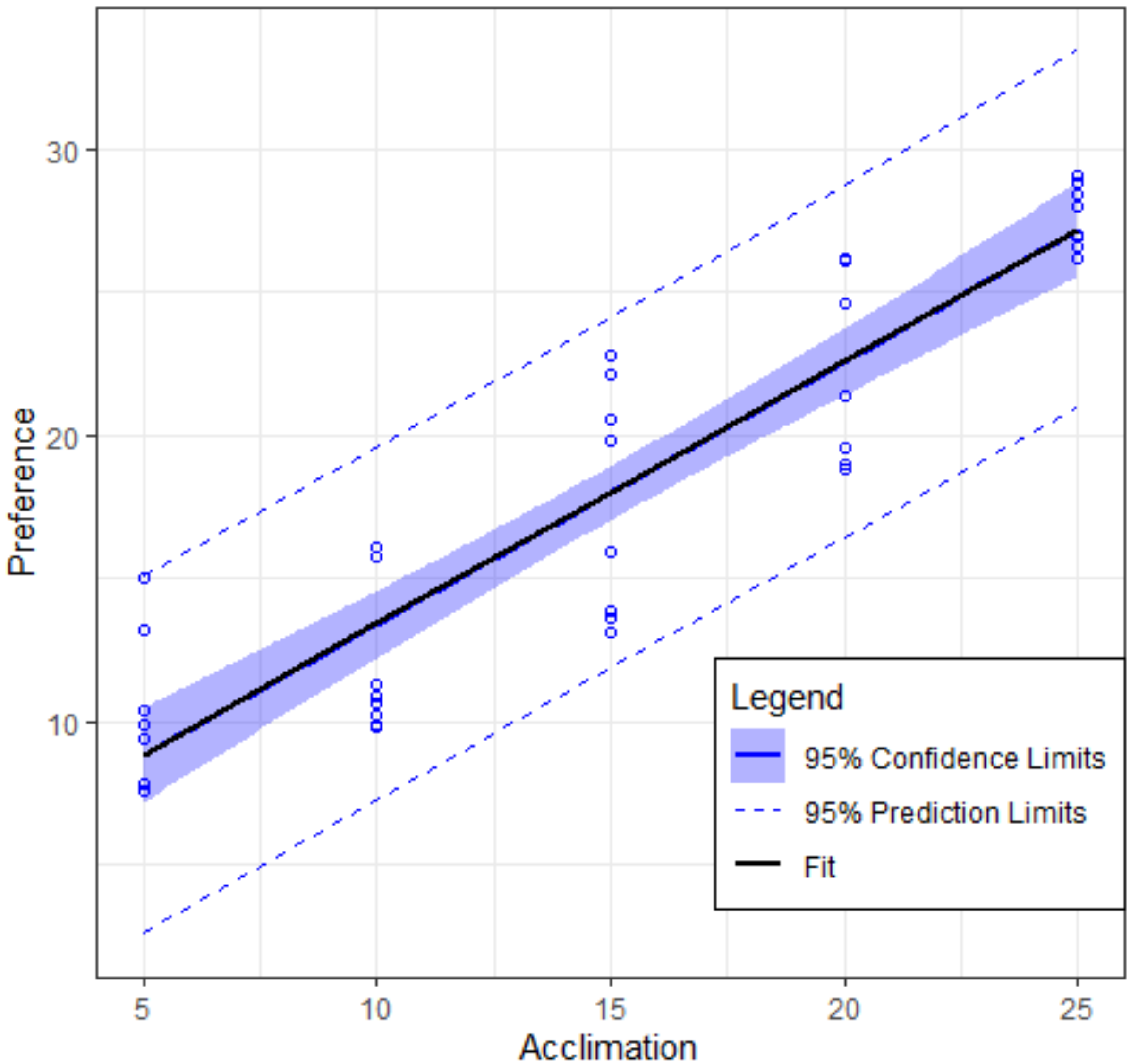

Figure 6. Graph showing the comparison between the acclimation temperature and the average preferred temperature of the Round Goby for each of the 5 trials: 5°C, 10°C, 15°C, 20°C, 25°C. Each trial includes eight different samples for a total of forty average preference points on the graph. Graph created by Jay Stauffer Jr. and Andrew Bucha III.

The analysis of variance helps evaluate the relationship of variation between Round Goby acclimation temperature and preference temperature. Using an F-distribution table (Table 3) with an alpha value of 0.05, and degrees of freedom (Df) of 1 and 9 respectively, an F-critical value of 5.1174 is obtained. According to Table 1, the calculated F-statistic is 190.2, which is significantly larger than the F-critical value of 5.1174. Additionally, the p-value provided by the ANOVA table is less than 0.0001, which is notably less than the alpha-value of 0.05 (Table 1).

Table 2. One-way ANOVA table showing the significance of the Round Goby temperature preference study results.

Source	Df	Sum Sq	Mean Sq	F-Value	Pr > F
Model	1	1684.53	1684.53	190.2	<.0001
Error	38	336.546	8.85647		
Corrected Total	39	2021.08			

Table 2 describes the strength of the correlation between acclimation temperature and the average preferred temperature of the Round Goby presented in the linear regression model (Figure 6). Because R^2 values can only range from 0 to 1, an R^2 value of 0.8335 and an adjusted R^2 value of 0.8291 (Table 2) suggest that the regression line “fits” the model well and does a suitable job explaining the variation in the data.

Table 3. Table showing the R and adjusted R values for the correlation between the acclimation temperature and the average preferred temperature of the Round Goby for each of the five trials: 5°C, 10°C, 15°C, 20°C, 25°C.

R-Squared	Adj R-Squared
0.8335	0.8291

The differences in preferred temperature and initial acclimation temperature of the Round Goby differs among trials (Figure 7). The lowest acclimation trial -- 5°C – shows the biggest difference between acclimation temperature and preferred temperature with a difference of 5.14°C. In contrast, the 10°C trial shows the smallest difference between the preferred temperature and acclimation temperature, with a difference of 1.825°C (Figure 7). It is important to note that although the difference between preference temperature and acclimation temperature in the 5°C is noticeably larger than the differences of the other trials, the difference between preference temperature and acclimation temperature is similar among the four remaining trials -- 10°C, 15°C, 20°C, 25°C – with the average preferred temperature ranging from 2°C to 4°C above the initial acclimation temperature.

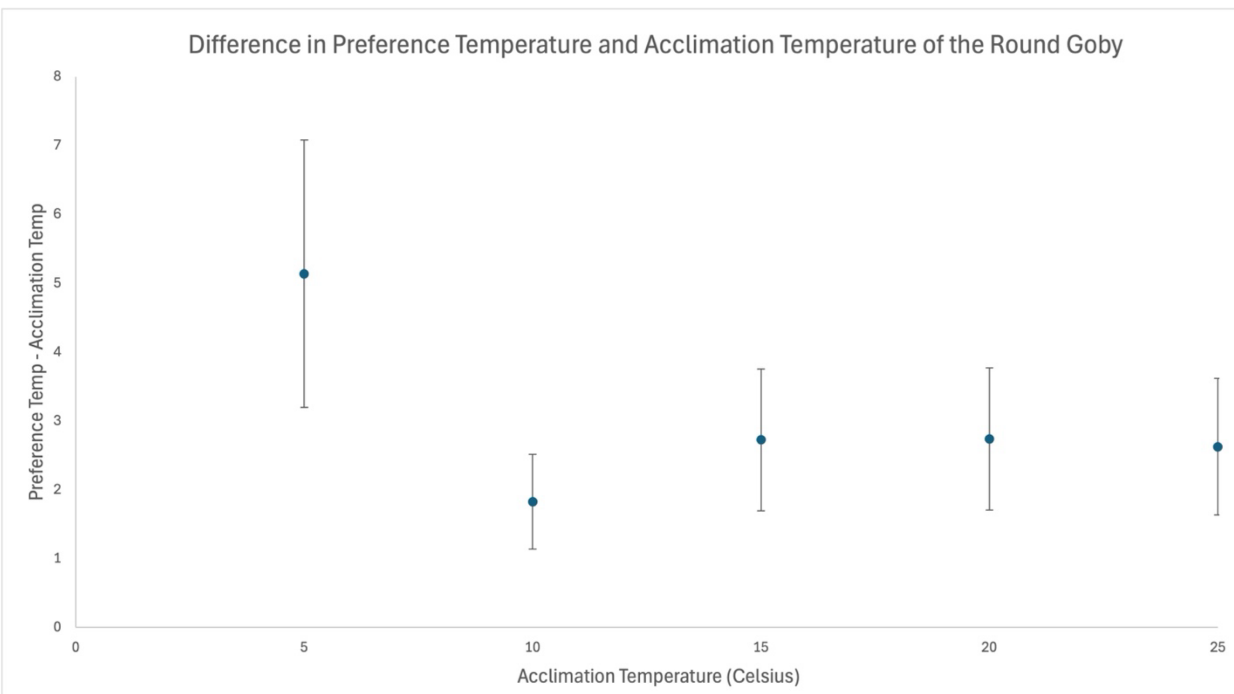

Figure 7. Graph showing the difference in the preference temperature and the acclimation temperature of the Round Goby for each of the five trials: 5°C, 10°C, 15°C, 20°C, 25°C. Standard deviation is represented by positive and negative error bars.

Past Temperature Preference Study Results

Figure 8 implies that there is a negative, and moderately linear relationship between the acclimation temperature and the difference between the preferred temperature and the acclimation temperature as the initial acclimation temperature increases. It is important to note that there is no difference between the preferred temperature and the acclimation temperature in the fifth trial, and the acclimation temperature is shown to be 1.5°C higher than the average preferred temperature of the Rock Bass during the sixth trial when the acclimation temperature is 32.7°C (Figure 8). The data also shows that the standard deviation of the differences in temperature decreases up until the fifth trial where the standard deviation is 0. However, the standard deviation increases slightly again during the final acclimation trial (Figure 8).

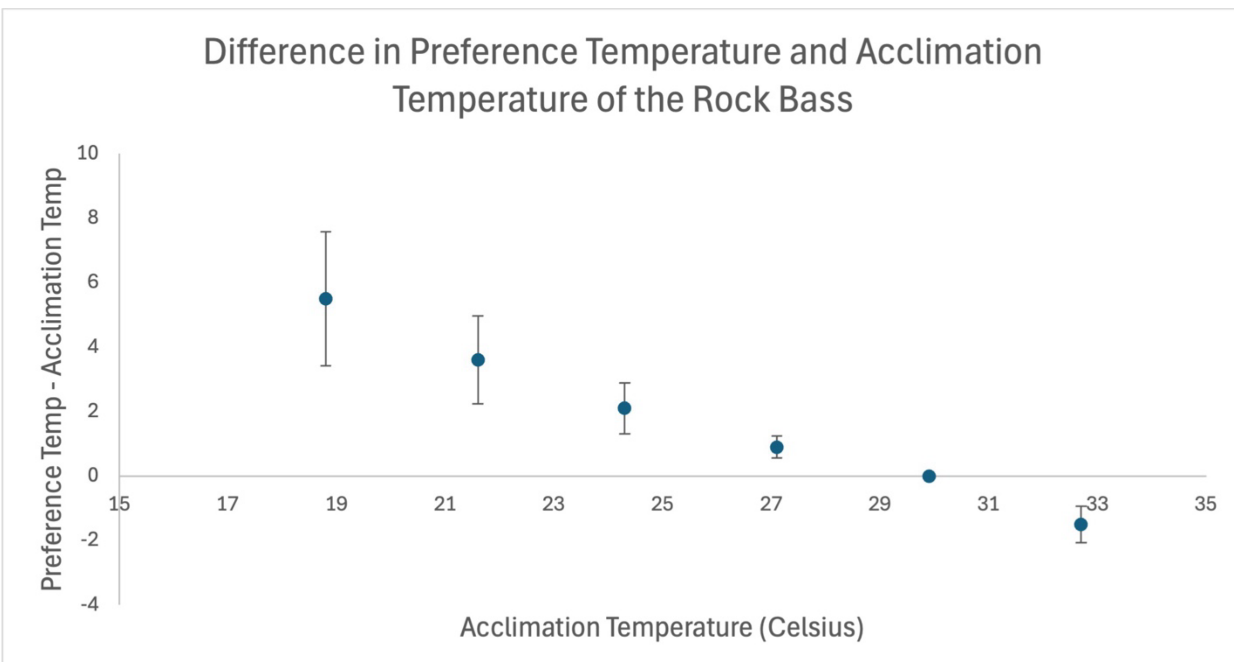

Figure 8. Graph showing the difference in the preference temperature and the acclimation temperature of the Rock Bass for each of six acclimation trials: 18.8°C, 21.6°C, 24.3°C, 27.1°C, 29.9°C, and 32.7°C. Standard deviation is represented by positive and negative error bars. Data obtained from Stauffer et al., 1976.

Figure 9 shows that there is a negative, and moderately linear relationship between the acclimation temperature and the difference between the preferred temperature and the acclimation temperature as the initial acclimation temperature increases. The graph implies that there is no difference between the preferred temperature and the acclimation temperature in the fifth trial, and the acclimation temperature is shown to be 1.1°C higher than the average preferred temperature of the Fathead Minnow during the sixth trial when the acclimation temperature is 29.2°C (Figure 9). The data also shows that the standard deviation of the differences in temperature decreases up until the fifth trial where the standard deviation is 0. However, the standard deviation increases slightly again during the final acclimation trial (Figure 9).

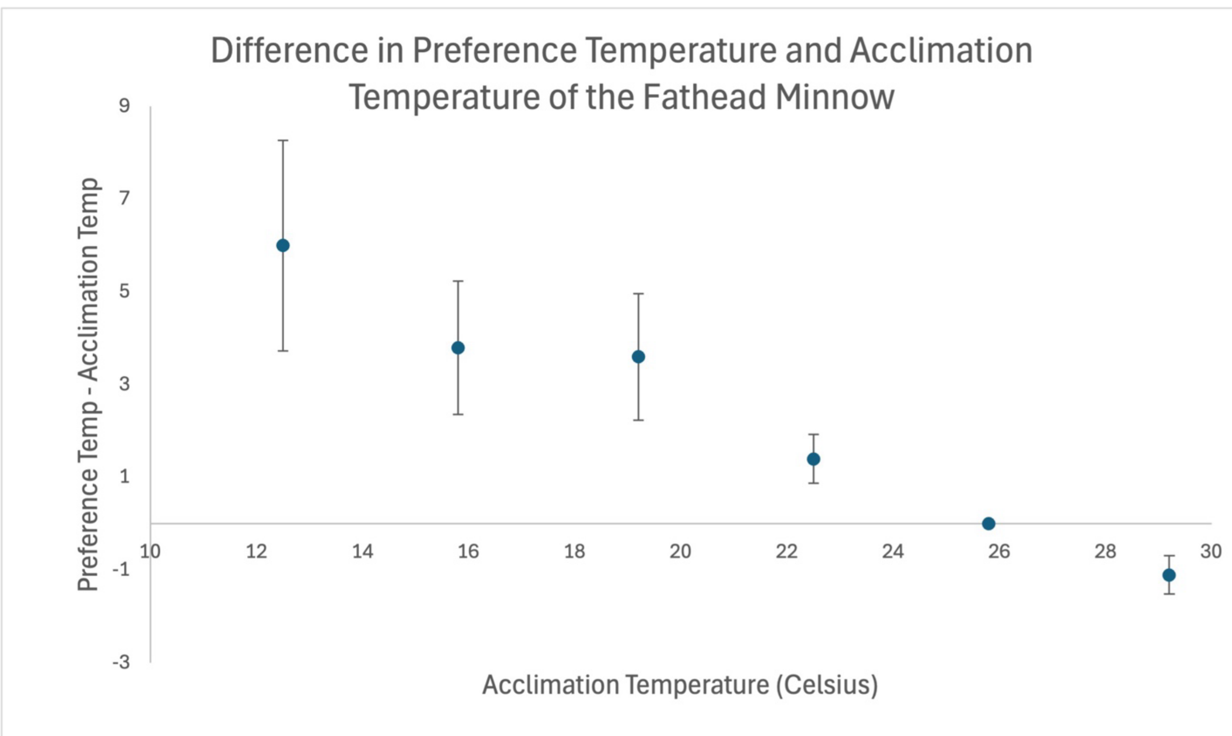

Figure 9. Graph showing the difference in the preference temperature and the acclimation temperature of the Fathead Minnow for each of six acclimation trials: 12.5°C, 15.8°C, 19.2°C, 22.5°C, 25.8°C, and 29.2°C. Standard deviation is represented by positive and negative error bars. Data obtained from Stauffer et al., 1976.

Figure 10 shows that there is a negative, and moderately linear relationship between the acclimation temperature and the difference between the preferred temperature and the acclimation temperature as the initial acclimation temperature increases. It is important to note that the acclimation temperature is shown to be 0.9°C higher than the average preferred temperature of the Bluntnose Minnow during the sixth trial when the acclimation temperature is 29.2°C (Figure 10). The data also shows that the standard deviation of the differences in temperature decreases up until the fifth trial where the standard deviation is 0. However, the standard deviation increases slightly again during the final acclimation trial (Figure 10).

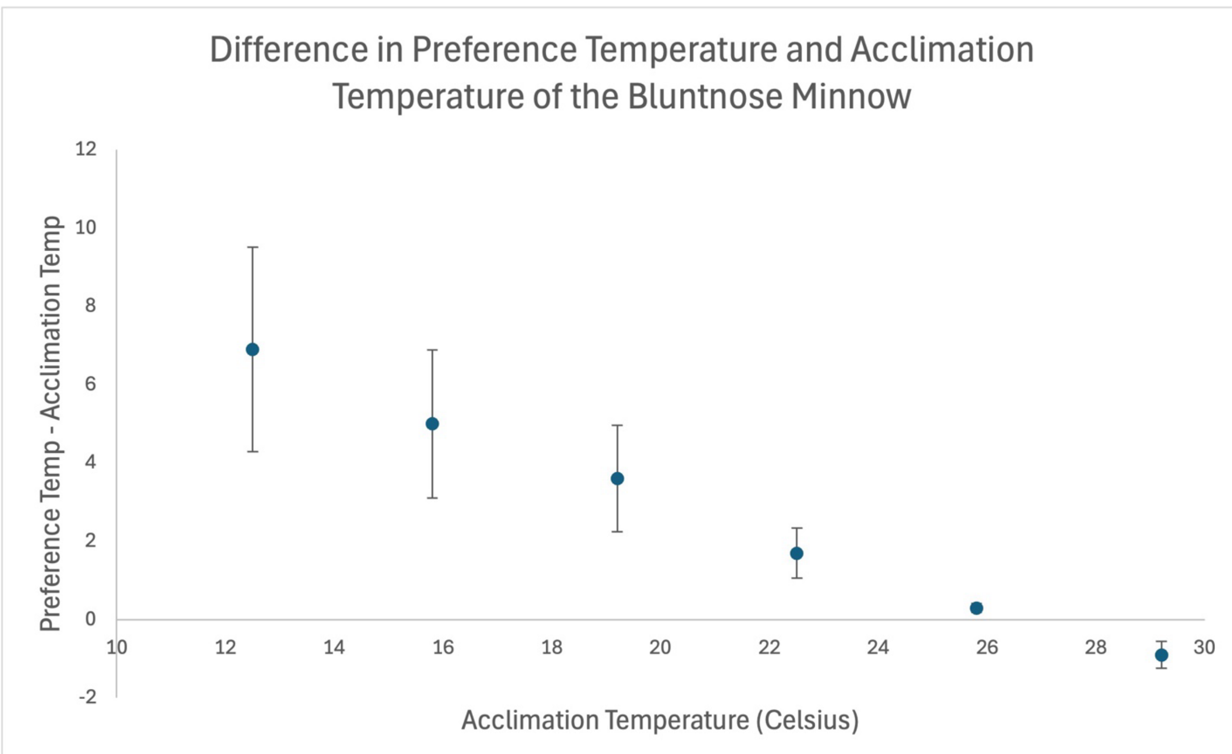

Figure 10. Graph showing the difference in the preference temperature and the acclimation temperature of the Bluntnose Minnow for each of six acclimation trials: 12.5°C, 15.8°C, 19.2°C, 22.5°C, 25.8°C, and 29.2°C. Standard deviation is represented by positive and negative error bars. Data obtained from Stauffer et al., 1976.

Based on Figure 11, there appears to be a negative and moderately linear relationship between the acclimation temperature and the difference between the preferred temperature and the acclimation temperature as the initial acclimation temperature increases. The lowest acclimation trial -- 5°C – shows the biggest difference between preference temperature and acclimation temperature with a value of 6.36°C (Figure 11). In contrast, the highest acclimation trial -- 25°C – shows the smallest difference between preference temperature and acclimation temperature with a value of 1.33°C (Figure 11). Although this model depicts a negative and linear relationship, it is important to note that the preference temperature is not smaller than the acclimation temperature for any of the trials (Figure 11). The data from Figure 11 also shows that the standard deviation of the differences in temperature decreases with each successive acclimation trial.

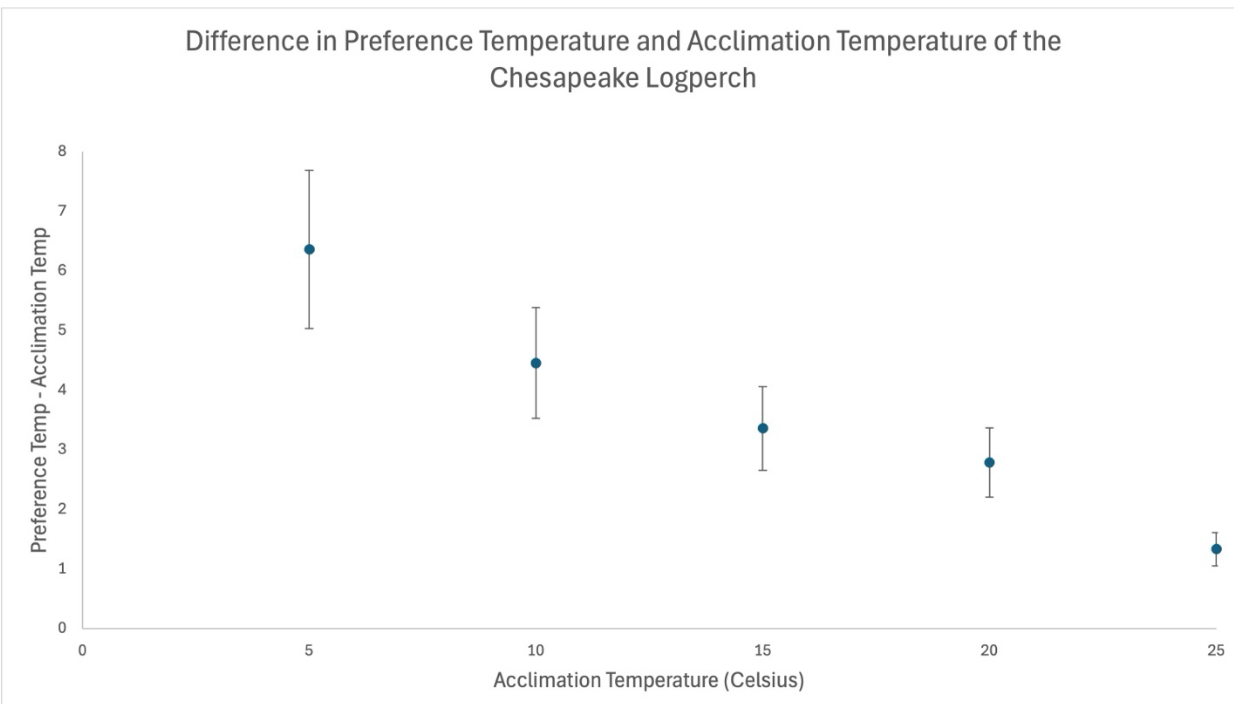

Figure 11. Graph showing the difference in the preference temperature and the acclimation temperature of the Chesapeake Logperch for each of the five trials: 5°C, 10°C, 15°C, 20°C, 25°C. Standard deviation is represented by positive and negative error bars. Data was obtained from Andrew Bucha III, a Penn State graduate student (2024).

Chapter 4: Discussion

The Thermal Preference and Thermal Tolerance of the Round Goby

The results of this temperature preference study offer crucial insight into how the Round Goby can dominate and prosper in a variety of freshwater ecosystems in North America from the Laurentian Great Lakes to Lake LeBoeuf in Erie, Pennsylvania. According to Figure 6, the average preferred temperature of the Round Goby differs significantly from the acclimation temperature in each of the five trials. This idea is supported by Table 1, which shows that the data produces an F-statistic of 190.2. When compared to the F-critical value of 5.1174, the F-statistic is much larger. This difference implies that we can reject our null hypothesis that there is no difference in the average preferred temperature among acclimation trials. Statistical significance is further supported by the p-value (<0.0001) being smaller than the alpha value of 0.05 (Table 1). This significance supports our initial prediction that the preferred temperature of the Round Goby is different from their initial acclimation temperature. This difference in temperature suggests that the Round Goby has a significantly large thermal tolerance range, implying that the species can survive – and even thrive – in a variety of freshwater ecosystems. This large thermal tolerance range is an advantage that many native North American species do not have, which could be a reason why the Round Goby is able to dominate so successfully in alien waters.

Moreover, the R^2 value of 0.8335 and the adjusted R2 value of 0.8291 provided in Table 2 suggest that the relationship between the acclimation temperature and the average preferred temperature is relatively strong and linear. This idea is supported by Figure 6, which shows that as the acclimation temperature increases, so do the average preferred temperatures of the Gobies. The strength of this relationship suggests that the initial acclimation temperature influences the preferred temperatures of the Round Gobies, even though there is significant variability in the average preferred temperature within each acclimation trial.

One of the main findings from this study suggests that the 95% confidence limits for the two most extreme trials – 5° C and 25° C – are larger than the confidence limits for the middle three trials (Figure 6). This result is interesting since we initially predicted that as the acclimation temperature increases, the variability in the average preferred temperature becomes smaller. According to Figure 6, this idea is supported by the preference data points, but not by the confidence limit for the line of best fit.

Overall, these findings suggest that Round Gobies can comfortably inhabit and tolerate a broad range of freshwater ecosystems. Since there is significant variability in the average preferred temperature both within and between all five acclimation trials, these results imply that the Round Goby does not have a specific preferred temperature. However, during our study, three fish "flipped" during the 25° C acclimation trial (see *Experimental Methods*), suggesting that the Round Goby cannot be successful and survive for long at temperatures above 25° C. Because fish exhibited a loss of equilibrium during this specific acclimation trial, we determined 25° C to be the Round Goby's maximum thermal tolerance. This claim is further supported by Figure 6, which shows that the range in average preferred temperature is smallest for the 25° C acclimation trial, suggesting that the Round Gobies could not stray far above their initial acclimation temperature without losing equilibrium.

Comparison of Results to Past Thermal Tolerance and Preference Studies

Comparing the results of the Round Goby temperature preference study to past thermal tolerance studies yields interesting results. One of the main findings resulting from the comparison between the Round Goby study and the three species studies (Rock Bass, Fathead Minnow, and Bluntnose Minnow) performed by Stauffer et al., 1976 is that the Round Goby has a significantly different temperature preference pattern compared to the historically studied species. Based on Figure 7, the average preference temperature of the Round Goby is greater than the acclimation temperature for each of the five trials. In contrast, the three species studied by Stauffer et al. (1976) all have a lower preference temperature than acclimation temperature for the highest acclimation trial. This pattern implies that the highest acclimation trial for each of these studies is representative of the maximum thermal tolerance for these three species. However, this pattern is not reflected in the Round Goby thermal tolerance study. Since the difference between preference temperature and acclimation temperature for the Round Goby is positive for all five trials, these findings further suggest that the Round Goby has a much larger thermal tolerance range compared to native North American freshwater species. This ability to survive and adapt to warming waters appears to be one of the main factors contributing to the Round Goby's success in out-competing native species. Furthermore, the native freshwater species' – such as the Rock Bass, Fathead Minnow, and Bluntnose Minnow – significantly lower thermal tolerances and inability to adapt to warming waters could further facilitate the Gobies' invasion and domination of foreign waters.

In contrast to the temperature studies conducted by Stauffer et al. (1976), the Chesapeake Logperch thermal tolerance trials conducted by Bucha (2024) provide results similar to those of the Round Goby study. For one, the Chesapeake Logperch model shows that the average preference temperature is higher than the acclimation temperature for each of the five trials (Figure 11). This pattern is similar to that of the Round Goby thermal tolerance study, suggesting that the Chesapeake Logperch also has a rather larger range of thermal tolerance. Significantly, both the Round Goby and the Chesapeake Logperch have similar thermal tolerances and temperature ranges because the Round Goby is a successful invasive species, and the Chesapeake Logperch is a threatened native North American species. Because both the Round Goby and Chesapeake Logperch temperature studies were performed in the past year, and the three species studies performed by Stauffer et al. (1976) were conducted almost 50 years ago, it would be interesting to see whether the thermal tolerances and ranges of these historical species have changed in response to warming inland waters. Overall, more research should be conducted on the thermal tolerances of the Round Goby and respective native species to determine whether the differences in thermal tolerance are the major factor contributing to the Round Goby's success and the native species' declines.

Limitations and Potential Biases

Although this study yields significant insight into the temperature preferences and thermal regulations of the Round Goby, it is still important to acknowledge the limitations and potential biases of the study. First, a relatively small sample size was used for each trial group. Because we only received a certain number of fish collected by the Pennsylvania Fish and Boat Commission, we had no choice but to keep our sample sizes in each trial small.

Additionally, because we decided to add a 5° C trial to the study after the fish had already been separated and placed in their aquarium acclimation tanks in Rock Springs, we had to reuse the group of fish that were initially sampled in the 10° C acclimation trial. Since these fish were used for two different temperature groups – 5° C and 10° C – there could be bias in the 5° C that was performed as an afterthought. Because the fish in the 5° C trial had already experienced the conditions of the temperature trough, their behavior during this trial might not accurately reflect the movements or preferences of a fish that was not already accustomed to the trough environment.

Moreover, because the five temperature trials were performed at different times over a four-month period (September to December), the fish analyzed at the end of the study period were significantly older than the fish examined at the beginning of the study period. The change in age and maturity between fish in the different trials could influence their thermal preference. This potential bias opens a door for further research into whether the thermal tolerance of the Round Goby changes with age and growth. Despite these limitations and biases, the findings of this study provide a solid base of knowledge that can be used in future research regarding the temperature preferences of the Round Goby and other invasive fish species.

Areas of Future Research

Although tolerance to changes in water temperature is a key factor that makes the Round Goby such a prolific invader of North American lakes and rivers, tolerance to other environmental conditions such as salinity should be studied as an aid to the Round Goby's success as well. As water temperature increases due to climate change, so do salinity levels. According to a study published by Donovan (2023), northern lakes in the United States and Canada have seen salinity levels rise from 3-5 milligrams per liter in the 1980s to 15-20 milligrams per liter in 2020. This change in salinity is sure to influence both invasive and native fish species. By performing additional research on the salinity preference and tolerance of the Round Goby, we will obtain a more well-rounded understanding of how this small, benthic fish has been able to dominate North American waters.

Furthermore, future studies could shed light on opportunities and strategies to prevent and manage the geographic spread of the Round Goby. Ultimately, although further research is necessary to fully understand the impact this invasive fish has – and will continue to have – on North American waters, this study has provided crucial initial insight into how rising temperatures have given the Round Goby the perfect opportunity to flourish and grow in an alien environment.

Appendix A: F-Distribution Table

Table 4. The F-Distribution Table was used to determine the F-critical value in the Round Goby study. Table obtained from Bobbitt, 2018.

	DF1	α = 0.05																	
DF2	1	2	3	4	5	6	7	8	9	10	12	15	20	24	30	40	60	120	Inf
1	161.45	199.5	215.71	224.58	230.16	233.99	236.77	238.88	240.54	241.88	243.91	245.95	248.01	249.05	250.1	251.14	252.2	253.25	254.31
2	18.513	19	19.164	19.247	19.296	19.33	19.353	19.371	19.385	19.396	19.413	19.429	19.446	19.454	19.462	19.471	19.479	19.487	19.496
3	10.128	9.5521	9.2766	9.1172	9.0135	8.9406	8.8867	8.8452	8.8123	8.7855	8.7446	8.7029	8.6602	8.6385	8.6166	8.5944	8.572	8.5494	8.5264
4	7.7086	6.9443	6.5914	6.3882	6.2561	6.1631	6.0942	6.041	5.9988	5.9644	5.9117	5.8578	5.8025	5.7744	5.7459	5.717	5.6877	5.6581	5.6281
5	6.6079	5.7861	5.4095	5.1922	5.0503	4.9503	4.8759	4.8183	4.7725	4.7351	4.6777	4.6188	4.5581	4.5272	4.4957	4.4638	4.4314	4.3985	4.365
6	5.9874	5.1433	4.7571	4.5337	4.3874	4.2839	4.2067	4.1468	4.099	4.06	3.9999	3.9381	3.8742	3.8415	3.8082	3.7743	3.7398	3.7047	3.6689
7	5.5914	4.7374	4.3468	4.1203	3.9715	3.866	3.787	3.7257	3.6767	3.6365	3.5747	3.5107	3.4445	3.4105	3.3758	3.3404	3.3043	3.2674	3.2298
8	5.3177	4.459	4.0662	3.8379	3.6875	3.5806	3.5005	3.4381	3.3881	3.3472	3.2839	3.2184	3.1503	3.1152	3.0794	3.0428	3.0053	2.9669	2.9276
9	5.1174	4.2565	3.8625	3.6331	3.4817	3.3738	3.2927	3.2296	3.1789	3.1373	3.0729	3.0061	2.9365	2.9005	2.8637	2.8259	2.7872	2.7475	2.7067
10	4.9646	4.1028	3.7083	3.478	3.3258	3.2172	3.1355	3.0717	3.0204	2.9782	2.913	2.845	2.774	2.7372	2.6996	2.6609	2.6211	2.5801	2.5379
11	4.8443	3.9823	3.5874	3.3567	3.2039	3.0946	3.0123	2.948	2.8962	2.8536	2.7876	2.7186	2.6464	2.609	2.5705	2.5309	2.4901	2.448	2.4045
12	4.7472	3.8853	3.4903	3.2592	3.1059	2.9961	2.9134	2.8486	2.7964	2.7534	2.6866	2.6169	2.5436	2.5055	2.4663	2.4259	2.3842	2.341	2.2962
13	4.6672	3.8056	3.4105	3.1791	3.0254	2.9153	2.8321	2.7669	2.7144	2.671	2.6037	2.5331	2.4589	2.4202	2.3803	2.3392	2.2966	2.2524	2.2064
14	4.6001	3.7389	3.3439	3.1122	2.9582	2.8477	2.7642	2.6987	2.6458	2.6022	2.5342	2.463	2.3879	2.3487	2.3082	2.2664	2.2229	2.1778	2.1307
15	4.5431	3.6823	3.2874	3.0556	2.9013	2.7905	2.7066	2.6408	2.5876	2.5437	2.4753	2.4034	2.3275	2.2878	2.2468	2.2043	2.1601	2.1141	2.0658
16	4.494	3.6337	3.2389	3.0069	2.8524	2.7413	2.6572	2.5911	2.5377	2.4935	2.4247	2.3522	2.2756	2.2354	2.1938	2.1507	2.1058	2.0589	2.0096
17	4.4513	3.5915	3.1968	2.9647	2.81	2.6987	2.6143	2.548	2.4943	2.4499	2.3807	2.3077	2.2304	2.1898	2.1477	2.104	2.0584	2.0107	1.9604
18	4.4139	3.5546	3.1599	2.9277	2.7729	2.6613	2.5767	2.5102	2.4563	2.4117	2.3421	2.2686	2.1906	2.1497	2.1071	2.0629	2.0166	1.9681	1.9168
19	4.3807	3.5219	3.1274	2.8951	2.7401	2.6283	2.5435	2.4768	2.4227	2.3779	2.308	2.2341	2.1555	2.1141	2.0712	2.0264	1.9795	1.9302	1.878
20	4.3512	3.4928	3.0984	2.8661	2.7109	2.599	2.514	2.4471	2.3928	2.3479	2.2776	2.2033	2.1242	2.0825	2.0391	1.9938	1.9464	1.8963	1.8432
21	4.3248	3.4668	3.0725	2.8401	2.6848	2.5727	2.4876	2.4205	2.366	2.321	2.2504	2.1757	2.096	2.054	2.0102	1.9645	1.9165	1.8657	1.8117
22	4.3009	3.4434	3.0491	2.8167	2.6613	2.5491	2.4638	2.3965	2.3419	2.2967	2.2258	2.1508	2.0707	2.0283	1.9842	1.938	1.8894	1.838	1.7831
23	4.2793	3.4221	3.028	2.7955	2.64	2.5277	2.4422	2.3748	2.3201	2.2747	2.2036	2.1282	2.0476	2.005	1.9605	1.9139	1.8648	1.8128	1.757
24	4.2597	3.4028	3.0088	2.7763	2.6207	2.5082	2.4226	2.3551	2.3002	2.2547	2.1834	2.1077	2.0267	1.9838	1.939	1.892	1.8424	1.7896	1.733
25	4.2417	3.3852	2.9912	2.7587	2.603	2.4904	2.4047	2.3371	2.2821	2.2365	2.1649	2.0889	2.0075	1.9643	1.9192	1.8718	1.8217	1.7684	1.711
26	4.2252	3.369	2.9752	2.7426	2.5868	2.4741	2.3883	2.3205	2.2655	2.2197	2.1479	2.0716	1.9898	1.9464	1.901	1.8533	1.8027	1.7488	1.6906
27	4.21	3.3541	2.9604	2.7278	2.5719	2.4591	2.3732	2.3053	2.2501	2.2043	2.1323	2.0558	1.9736	1.9299	1.8842	1.8361	1.7851	1.7306	1.6717
28	4.196	3.3404	2.9467	2.7141	2.5581	2.4453	2.3593	2.2913	2.236	2.19	2.1179	2.0411	1.9586	1.9147	1.8687	1.8203	1.7689	1.7138	1.6541
29	4.183	3.3277	2.934	2.7014	2.5454	2.4324	2.3463	2.2783	2.2229	2.1768	2.1045	2.0275	1.9446	1.9005	1.8543	1.8055	1.7537	1.6981	1.6376
30	4.1709	3.3158	2.9223	2.6896	2.5336	2.4205	2.3343	2.2662	2.2107	2.1646	2.0921	2.0148	1.9317	1.8874	1.8409	1.7918	1.7396	1.6835	1.6223
40	4.0847	3.2317	2.8387	2.606	2.4495	2.3359	2.249	2.1802	2.124	2.0772	2.0035	1.9245	1.8389	1.7929	1.7444	1.6928	1.6373	1.5766	1.5089
60	4.0012	3.1504	2.7581	2.5252	2.3683	2.2541	2.1665	2.097	2.0401	1.9926	1.9174	1.8364	1.748	1.7001	1.6491	1.5943	1.5343	1.4673	1.3893
120	3.9201	3.0718	2.6802	2.4472	2.2899	2.175	2.0868	2.0164	1.9588	1.9105	1.8337	1.7505	1.6587	1.6084	1.5543	1.4952	1.429	1.3519	1.2539
Inf	3.8415	2.9957	2.6049	2.3719	2.2141	2.0986	2.0096	1.9384	1.8799	1.8307	1.7522	1.6664	1.5705	1.5173	1.4591	1.394	1.318	1.2214	1

BIBLIOGRAPHY

Becker, C. D. 1973. Columbia River thermal effects study, reactor effluent problems. J. Wat. Poll. Contr. Fed. 45:850–869.

Bobbitt, Z. 2018. F distribution table. https://www.statology.org/f-distribution-table/.

Brett, J. R. 1956. Some principles in the thermal requirements of fishes. Quart. Rev. Biol. 31:75 87.

Bucha, A. 2024. Experimental Evaluation of Salinity Tolerance of Chesapeake Logperch with Implications for Range Expansion. Thesis.

Clark, K.H., Iwanowicz, D.D., Iwanowicz, L.R. *et al.* 2022. Freshwater unionid mussels threatened by predation of Round Goby (*Neogobius melanostomus*). *Sci Rep* **12**, 12859.

Climate Change Indicators: Great Lakes Ice Cover. 2021. Environmental Protection Agency. https://www.epa.gov/climate-indicators/climate-change-indicators-great-lakes-ice-cover.

Collingsworth, P. D., D. B. Bunnell, M. W. Murray, Y.-C. Kao, Z. S. Feiner, R. M. Claramunt, B. M. Lofgren, T. O. Höök, and S. A. Ludsin. 2017. Climate change as a long-term stressor for the fisheries of the Laurentian Great Lakes of North America. Reviews in Fish Biology and Fisheries 27(2):363–391.

Dean, J. M. and C. C. Coutant. 1968. Lethal temperature relations of juvenile Columbia River Chinook Salmon, Sec. 9.5 In: Annual Report. Vol. I. Biological Sciences BNWL-718. Battelle Pacific Northwest Labs. Richland, WA.

Donovan, R. 2023. Lake Michigan's salinity is on the rise. https://eos.org/articles/lake-michigans-salinity-is-on-the-rise.

Drost-Hansen, W. 1965. The effects on biologic systems of higher-order phase transitions in water. Ann. N. Y. Acad. Sci. 125:471–501.

Fisher, R. G. 1958. The preferred temperatures of fish and their mid-summer distribution in temperate lakes and streams. J. Fish. Res. Bd. Can. 15:607–624.

Freedman, J.A., Fuller, P., Benson, A., Maynard, E., Neilson, M.E., Larson, J., Fusaro, A., and R. Sturtevant. 2025. *Neogobius melanostomus* (Pallas, 1814): U.S. Geological Survey, Nonindigenous Aquatic Species Database, Gainesville, FL, https://nas.er.usgs.gov/queries/factsheet.aspx?SpeciesID=713.

Gift, J. J. 1970. Responses of some estuarine fishes to increasing thermal gradients. Ph.D. Dissert., Rutgers Univ. New Brunswick, NJ.

Janssen, John, and David J. Jude. 2001. “Recruitment Failure of Mottled Sculpin Cottus Bairdi in Calumet Harbor, Southern Lake Michigan, Induced by the Newly Introduced Round Goby Neogobius Melanostomus.” *Journal of Great Lakes Research*, vol. 27, no. 3,pp. 319–328, doi:10.1016/s0380-1330(01)70647-8.

Johnson, Timothy B., et al. 2009. “Comparison of Methods Needed to Estimate Population Size of Round Gobies (Neogobius Melanostomus) in Western Lake Erie.” *Journal of Great Lakes Research*, vol. 31, no. 1, pp. 78–86, doi:10.1016/s0380-1330(05)70239-2.

Kelley, A. L. 2014. “The Role Thermal Physiology Plays in Species Invasion.” *Conservation Physiology*, vol. 2, no. 1, doi:10.1093/conphys/cou045.

Kusakina, A. A. 1963. Relation of muscle and cholinesterase thermostability in certain fishes to specific environmental temperature conditions. Fed. Proc. Am. Soc. Exp. Biol. 22:T123–T126.

Lauer, Thomas E., et al. 2011. “Changes in Mottled Sculpin and Johnny Darter Trawl Catches after the Appearance of Round Gobies in the Indiana Waters of Lake Michigan.” *Transactions of the American Fisheries Society*, vol. 133, no. 1, pp. 185–189, doi:10.1577/t02-123.

Mayer, A. G. 1914. The effects of temperature upon tropical marine animals. Pap. Tortugas Lab. 6:1–24.

Mishra, V., K. A. Cherkauer, and L. C. Bowling. 2011. Changing Thermal Dynamics of lakes in the Great Lakes region: Role of ice cover feedbacks. Global and Planetary Change 75(3–4):155–172.

Mueller, S., Stauffer, J. R., Wisor, J., & Bradshaw-Wilson, C. 2017. Expansion of the invasive Round Goby (*Neogobius melanostomus*) into Allegheny River tributaries: LeBoeuf and French Creeks in Pennsylvania. *Journal of the Pennsylvania Academy of Science*, *91*(2), 105–111.

NOAA (National Oceanic and Atmospheric Administration). 2021. Great Lakes Environmental Research Laboratory: Historical ice cover. www.glerl.noaa.gov/data/ice/#historical.
Orr, P. R. 1955. Heat death, I. Time-temperature relationships in marine animals. Physiol. Zool. 28:290–294.

Pegel, B. A. and V. A. Remorov. 1961. Effect of heating and cooling of water on the gas exchange and blood lactic acid concentration of fish adapted to a certain temperature. Nounch. Dolk. Vyosh. Shk. Biol. Waukl. 1:58–61.

Penn State. 2019. "Invasive Round Gobies may be poised to decimate endangered French Creek mussels." ScienceDaily. www.sciencedaily.com/releases/2019/04/190401142207.html.

Phillips, Edward C., et al. 2009. “The Round Goby (Neogobius Melanostomus) in Pennsylvania Tributary Streams of Lake Erie.” *Journal of Great Lakes Research*, vol. 29, no. 1, pp. 34–40, doi:10.1016/s0380-1330(03)70413-4.

Stauffer, J. R., Jr., K. L. Dickson, J. Cairns, Jr., and D. S. Cherry. 1976. The potential and realized influences of temperature on the distribution of fishes in the New River, Glen Lyn, Virginia. Wildlife Monographs 50:1-40.

Stauffer, Jr., J. R., R. W. Criswell, and D. P. Fischer. 2016. The fishes of Pennsylvania. Cichlid Press. 556 pp.

Zerebecki RA, Sorte CJB. 2011. Temperature Tolerance and Stress Proteins as Mechanisms of Invasive Species Success. PLoS ONE 6(4): e14806. Great Lakes of North America. Reviews in Fish Biology and Fisheries 27(2):363–391.

ACADEMIC VITA

Molly Carson
mbc5999@psu.edu
mcarson737@gmail.com

EDUCATION

The Pennsylvania State University
University Park, PA
B.S. in Wildlife and Fisheries Science: Fisheries Option
Minors: Marine Science; Biology
Anticipated graduation date: May 2025

Schreyer Honors College
Honors Curriculum:

Function and Development of Organisms	Fishery Management
General Fishery Science	Symbiosis
Reptiles and Amphibians	

*Honors Thesis***:** The Determination of Temperature Tolerance and Preference on the Adult Round Goby (*Neogobius melanostomus*)

Other Relevant Courses

Population Dynamics	Wildlife and Fisheries Conservation
Fisheries Measurements	Biology: Populations and Communities
Intermediate Applied Statistics	Ichthyology

RESEARCH EXPERIENCE

SFS Turks and Caicos Study Abroad Program (*July-August 2023*)
Marine Megafauna Ecology and Conservation

PSU Marine Biology Florence Study Abroad (*May 2024*)
Environmental Marine Biology and Sustainability

AWARDS

President Sparks Award (*Spring 2022, Spring 2023*)
Outstanding Undergraduate in the Sophomore Class (*Spring 2023*)
Penn State Swim Team Academic Excellence Award (*Spring 2023, Spring 2024*)
Academic All-Big Ten Award (*Spring 2023, Spring 2024*)
Dean's List (*Fall 2021, Spring 2022, Fall 2022, Spring 2023, Fall 2023, Spring 2024*)

PRESENTATIONS

Cratena peregrina: A Preliminary Analysis of Habitat Preference Considering Reproduction and Growth. 2024 Elba Island Marine Biology Student Symposium.

CERTIFICATIONS

PADI Open Water Diver
PADI Advanced Open Water Diver

ACTIVITIES

Penn State Women's Varsity Swim Team (*Summer 2021-Present*)
Student-Athlete Advisory Board Pride Committee (*Fall 2022-Spring 2024*)
Penn State Athletic Director's Leadership Institute (*Fall 2022-Present*)
SAAB: Student Welfare and Development Committee (*Fall 2023-Present*)