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The Effects of Elevated Temperature on the Growth and Size of the Ribbed Mussel Geukensia demissa

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The Effects of Elevated Temperature on the Growth and Size of the Ribbed Mussel *Geukensia demissa*

By

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CERTIFICATE OF APPROVAL

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Honors Thesis

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Abstract

The impact of elevated water temperatures on the growth of the ribbed mussel *Geukensia demissa* was examined in order to assess the effects of temperature increases due to climate change predicted by the Intergovernmental Panel on Climate Change. Fifty-seven mussels were distributed into treatments of 23°C, 27°C, and 31°C for 31 days. Measurements of weight, length, and width were compared. There was no significant impact on growth rates in varied temperatures. Mussels exposed to 31°C had the largest average shell length. Average shell length was found to be similar at 23°C and 27°C. Total change in average size was calculated to show growth differences among treatments. Mussels that were kept in 31°C showed the greatest change in weight and shell length. These results suggest that mussel shell size is positively correlated to temperature. However, in order to gain a clearer understanding of how temperature impacts *G. demissa* shell size a longer study may be necessary.

Introduction

Geukensia demissa, commonly known as the Atlantic Ribbed Mussel, is found along the east coast of North America. Its distribution is from the Gulf of St. Lawrence to Florida and through the Gulf of Mexico to Yucatan (Brousseau 1984). It is the bivalve that is typically highest in the intertidal zones in its range. This means it spends the majority of time exposed to air and constantly encounters environmental stress (Fields et al. 2014). It can survive temperatures as high as 45°C. The species inhabits salt marshes and is important to the salt marsh ecosystem. It deposits nitrogenous wastes onto sediments which provide the salt marshes with nutrients. This species also prevents erosion in its habitats by its interaction with the cordgrass *Spartina alterniflora* (Jost & Helmuth 2007). By its deposition of nitrogenous waste *G. demissa* positively influences the growth of *S. alterniflora.* This enhances productivity in salt marshes

and reduces erosion (Bertness 1984). *G. demissa* contributes to water clarity by filtering large volumes of water. Jordan and Valiela (1982) were able to show that *G. demissa* can filter larger volumes of water than the tidal volume of a marsh. The importance of this species makes it valuable in determining how the future impacts of climate change may affect it.

Sea surface temperatures are predicted to increase by 1.5 to 2.6ºC by the end of the century. This is the result of elevated carbon dioxide concentrations in the atmosphere. G. S. Callendar discovered that doubling carbon dioxide emissions increased the mean global temperature by 2°C. Studies from 1906 to 2005 revealed that average global surface temperatures rose by 0.74°C in the span of 100 years (Solomon et al. 2007). The trend in the accumulation of carbon dioxide and the rise of temperature is tied to human population growth, industrialization, and use of fossil fuels (Singh 2013). Approximately 80% of excess heat generated by the increase in carbon dioxide concentrations has been absorbed by oceans. Assessments by the Intergovernmental Panel on Climate Change have indicated that global ocean temperatures have increased by 0.11 ºC per decade in the upper 75 m of the ocean since 1971 (Solomon et al. 2007).

Marine communities and ecosystems will likely experience changes in climate that will affect survival, reproduction, and community structure. Effects will vary depending upon species' sensitivity, and environmental requirements. Identification of species' tolerances, vulnerabilities, and environmental necessities can indicate how distribution, abundance, and community structure will be effected (Johnson & Welch 2010). Species that are likely to experience the negative effects of warming are those with a narrow range of thermal tolerances and an inability to adjust to large temperature changes (Tewksbury et al. 2008). This creates concern for species living in intertidal zones where they are regularly exposed to the edge of

their thermal limits (Jost & Helmuth 2007). Species inhabiting tropical regions are also closer to their maximum thermal tolerances (Compton et al. 2007). These species can reveal changes in climate as species' distribution and community structure is altered (Jost & Helmuth 2007).

Mussels are expected to be affected by the changes in temperature due to climate change by reducing their growth, propagative success, and survival (Ganser et al. 2013). However, a study by Bartsch et al. (2003) showed that temperature was negatively correlated to survivorship but positively correlated to growth of juvenile mussels. As the maximum thermal threshold is reached by the species the survivorship began to decrease (Ganser et al. 2013). Growth rate of mussels is expected to increase with rising temperatures (Brousseau 1984). In comparative studies of *Macoma balthica*, it was found that individuals in colder regions exhibited lower growth rates, smaller maximum sizes, and greater longevity (Bachelet 1980).

In this study the effect of temperature on the growth of the mussel *Geukensia demissa* was quantitatively assessed. Laboratory conditions simulated the projected sea temperatures that will increase by at least 1°C and the current average temperatures of seawater in St. Petersburg, Florida. Measurements of weight, length, and width were recorded in order to compare the changes of overall growth and growth rate with varying temperatures. The data will provide a short term evaluation of the effects of climate change through rising temperatures on the intertidal species *G. demissa.*

Materials and Methods

Fifty-seven *G. demissa* specimens, 9 mm to 30 mm long, were collected from Weedon Island in St. Petersburg, Florida during January, 2015. They were exposed to three different temperature treatments. Temperature ranges for the study were determined by using the current

records of coastal water temperatures in St. Petersburg provided by NOAA Satellite and Information Service (NOAA 2015). The control treatment was 23°C. This was the average coastal water temperature from December 2013 until July 2014. The highest coastal water temperature during this time was 30°C. The highest temperature used in the present study was 31°C since temperatures were predicted to increase by at least 1°C. An intermediate temperature of 27°C was used as the second experimental temperature. Aquarium systems included a 57 L glass aquarium and two 38 L glass aquariums attached with Tetra Whisper Power Filters, Tetra Whisper Air Pumps, and heaters. Aquarium water was made using deionized water and Instant Ocean Salt Mix. The salinity was measured with a hydrometer and maintained at 26 ppt. Each system was allowed 37 days to regulate before the addition of mussels.

At the start of the experiment all mussels were placed into the control treatment in order to prevent heat shock and to allow them to adjust to the experimental temperatures in increments. Experimental treatment tanks were set at approximately 24°C. Seventeen mussels were distributed into each experimental tank and 23 were left in the control system. Mussels were distributed this way in case of mortalities at the start of the experiment in the warmer tanks. The control tank was also larger and contained approximately 57 L of water. The experimental tanks held roughly 38 L of water each. Temperatures were raised in 1-2°C increments over the course of 10 days until the final experimental temperatures were reached. Once these temperatures were set the initial measurements of weight, length, and width of each mussel were recorded for each system using a mass scale and slide caliper. The feeding protocol used each day was the distribution of 0.281 mL of Shellfish Diet 1800 per mussel (Reed Mariculture Inc 2015). In the control tank 500 mL of treatment water was mixed with 6 mL of Shellfish Diet 1800 and dispersed into the control system. In the experimental systems 500 mL of treatment water was

mixed with 4.8 mL of Shellfish Diet 1800 and distributed into experimental tanks. Measurements of growth in the form of weight, length, and width were taken once per week, every 7 days. The experiment lasted a total of 31 days. Final measurements were recorded on the 31st day.

Averages of weight, length, and width were recorded for each system at each time of measurement. In order to obtain growth rates during treatments the initial average measurements were subtracted from averages each week and divided by the amount of days since the treatments began. A one-way ANOVA was used to compare average length differences and growth rates in length among treatments. A MANOVA was performed to assess whether weight, length, and width were independently affected by temperature. Growth rates in weight, length, and width were tested using the same analysis. All mussel weights, lengths, and widths were not equal in each treatment at the start of the study. Changes in size for each treatment were calculated by total change in average size. This was done by subtracting initial average sizes from final average sizes.

Results

Average shell length was significantly larger in mussels exposed to a temperature of 31°C. Mussels treated with 31°C had a mean shell length of 19.01 mm. Mussels in temperatures of 23°C and 27°C shared similar average shell lengths. The average lengths under these conditions were 16.49 mm and 16.41 mm respectively (Fig. 1). Growth rates in length showed no significant degree of variation according to treatment (Fig. 2).

Weight, length, and width were independently affected by temperature according to a MANOVA. A Wilk's lambda value of 0.03780 and a value of p=0 indicated that differences in weight, length, and width among treatments were not related. However, length and width were

found to be positively correlated when plotted against each other. Regressions for length and width for each treatment, with the exception of 27°C, resulted in an R squared value of approximately 0.82-0.83. Growth rates in weight, length, and width were not independently affected by temperature when compared by MANOVA.

Total change in average size was greatest in mussels exposed to 31ºC. Average weight increased by 0.19 g and average length increased by 2.92 mm from the start of the experiment. Mussels treated with 27ºC showed the least total change in average size (Table 1 & Fig. 3). Average weight increased by 0.07 g and average length increased by 0.82 mm from the start of the study. Increases in size were lowest at this temperature.

Discussion

Temperature has been shown to have a positive effect on mussel size when thermal thresholds for survival are not exceeded. The results from the experiment indicate that at elevated temperatures mussel sizes are larger. Total change in average size provides evidence that at a temperature of 31°C there is a greater increase in average shell size compared to lower temperatures. This may indicate that growth of mussels was enhanced at an increased temperature. A similar result occurred in a study that examined the effects of temperature on growth of larva using shell length in the green mussel *Perna viridis.* Shell length was noticeably larger in larva that were reared in a temperature of 31°C compared to those in 24°C. The significant difference in growth can be attributed to increased metabolic processes and feed assimilation at higher temperatures (Nair R & Appukuttan 2003). Length was used as the main point of focus in the current study. Weight fluctuated throughout the experiment due to wet weight measurements. This may be because of variations in water weight on the specimen at the time of data collection. Width is likely related to length and showed a positive correlation when

tested through a regression. Length was chosen for data analysis over width because changes in length were easier to detect.

Another study demonstrated that growth rate in length was initially faster in mussels placed in higher temperatures. This was followed by a sharp decline after exposure for 5-10 days or 10-20 days depending on the season. At about 8 to 9 weeks mussels showed a significant decrease in shell size at the highest temperature with a negative regression of temperature and growth rate in length (Nielsen 1988). Growth rates were compared in the present study, but no significance was found among growth rates under varying temperatures. This could be because the study was not conducted for a long enough time period. Acclimation time may also be tied to fluctuations in growth among treatments. Allowing about 7 weeks of acclimation time can minimize misrepresentative results due to stress (Nielsen 1988). An acclimation period of 7 weeks was not used in the present study and may have affected growth rate outcomes. Furthermore, growth rates may have not been significant enough to show the impact of temperature because they were too low. Small growth rates under laboratory settings may be due to inadequate diet or unfavorable conditions (Ganser et al. 2013)

Anticipated rises in stress as a result of climate change will lead to variant effects among species in increasing temperatures (Petes et al. 2007). It is important to determine how *G. demissa* may be impacted by temperature increases due to its role in marsh ecosystems. In this study *G. demissa* showed a noticeable size difference in 31°C, the highest temperature it was exposed to. Mussel size was larger at this temperature compared to others. This suggests that mussel size is positively correlated to temperature. However, in order to gain a clearer understanding of how temperature impacts *G. demissa* shell size a longer study of 8 weeks may be necessary. A larger sample size and more trials may provide more suitable results. Specimens

equally distributed in size among temperature treatments will yield greater accuracy. The use of a field study could offer additional evidence to support the data and lead to more precise predictions of the impacts of temperature on mussel size and growth.

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References

Bachelet, G. (1980) Growth and recruitment of the Tellinid Bivalve *Macoma balthica* at the southern limit of its geographical distribution, the Gironde Estuary (SW France). Marine Biology, 59, 105-117.

Bartsch, M. R., Newton, T. J., Allran, J. W., O'Donnell, J. A., Richardson,W. B. (2003) Effects of pore-water ammonia on in situ survival and growth of juvenile mussels (*Lampsilis cardium*) in the St. Croix Riverway, Wisconsin, USA. Environmental Toxicology and Chemistry, 22(11), 2561-2568.

Bertness, M. D. (1984) Ribbed mussels and *Spartina alterniflora* production in a New England salt marsh. Ecology, 65(6), 1794-1807.

Brousseau, D. J. (1984) Age and growth rate determinations for the Atlantic ribbed mussel, Geukensia demissa Dillwyn (Bivalvia: Mytilidae). Estuaries, 7(3), 233-241.

Compton, T. J., Rijkenberg, M. J. A., Drent, J., Piersma, T. (2007) Thermal tolerance ranges and climate variability: A comparison between bivalves from differing climates. Journal of Experimental Marine Biology and Ecology, 352, 200-211.

Fields, P. A., Eurich, C., Gao, W. L., Cela, B. (2014) Changes in protein expression in the salt marsh mussel *Geukensia demissa*: evidence for a shift from anaerobic to aerobic metabolism during prolonged aerial exposure. The Journal of Experimental Biology, 217, 1601-1612.

Ganser, A. M., Newton, T. J., Haro R. J. (2013) The effects of elevated water temperature on native juvenile mussels: implications for climate change. BioOne, 32(4), 1168-1177.

Johnson, J. E. & Welch, D. J. (2010) Marine fisheries management in a changing climate: A review of vulnerability and future options. Reviews in Fisheries Science, 18(1), 106–124.

Jordan, T. E., Valiela, I. (1982) A nitrogen budget of the ribbed mussel, *Geukensia demissa*, and its significance in nitrogen flow in a New England salt marsh. Limnology and Oceanography, 27(1), 75-90.

Jost, J., Helmuth, B. (2007) Morphological and ecological determinants of body temperature of Geukensia demissa, the Atlantic ribbed mussel, and their effects on mussel mortality. The Biological Bulletin, 213, 141-151.

Lent, C. M. (1969) Adaptations of the ribbed mussel, *Modiolus demissus* (Dillwyn), to the intertidal habitat. American Zoologist, 9(2), 283-292.

Nair R., M. & Appukuttan, K. K. (2003) Effect of temperature on the development, growth, survival and settlement of green mussel *Perna viridis* (Linnaeus, 1758). Aquaculture Research, 34, 1037-1045.

Nielsen, M. V. (1988) The effect of temperature on the shell-length growth of juvenile *Mytilus edulis* L. Journal of Experimental Marine Biology and Ecology, 123, 227-234.

NOAA (2015) Water Temperature Table of the Southern Atlantic Coast. National Oceanographic Data Center. https://www.nodc.noaa.gov/cwtg/satl.html

Petes, L. E. Menge, B. A., Murphy, G. D. (2007) Environmental stress decreases survival, growth, and reproduction in New Zealand mussels. Journal of Experimental Marine Biology and Ecology, 351, 83-91.

Singh, U. (2013) Carbon capture and storage: an effective way to mitigate global warming. Current Science, 105(7), 914-922.

Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (2007) Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Tewksbury, J. J., Huey, R. B., Deutsch, C. A. (2008) Putting the heat on tropical animals. Science, 320, 1296-1297.

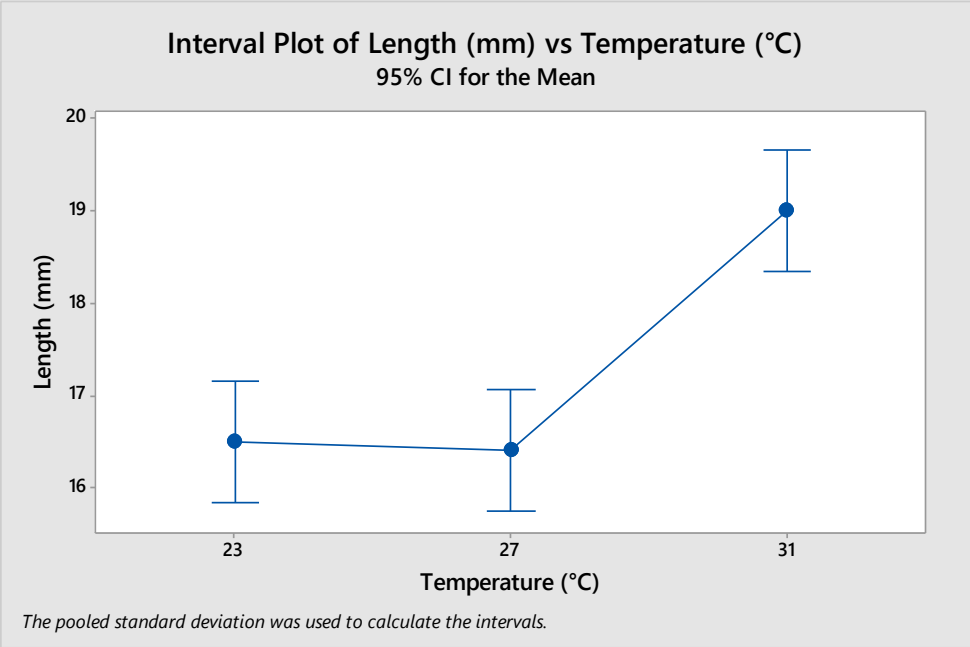

Fig. 1. Average lengths in mm per treatment per week were analyzed with ANOVA. Error bars indicate 95% confidence intervals with p=0.

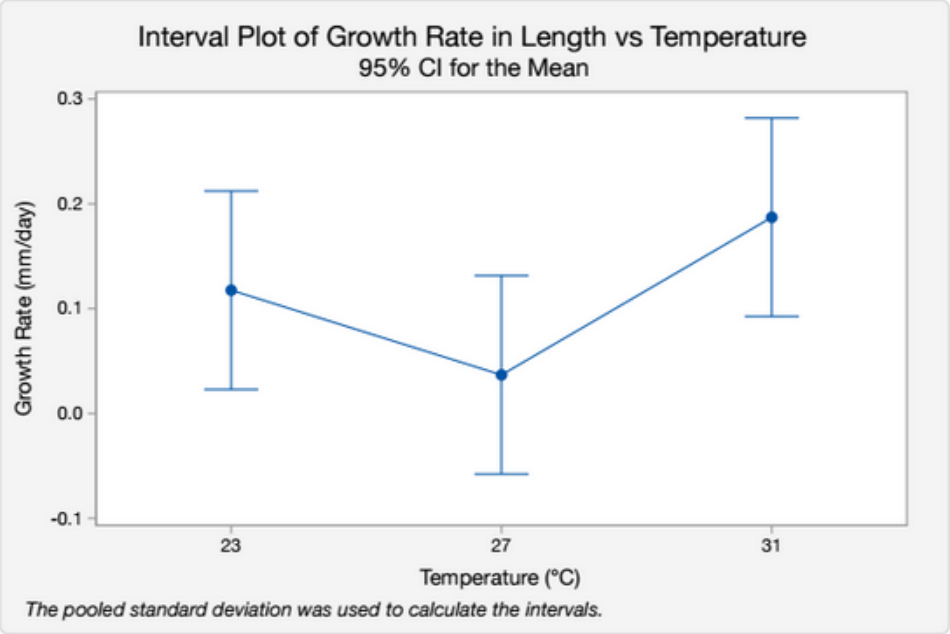

Fig. 2. Mean growth rates in length per week were used for comparison using ANOVA. Error bars show 95% confidence intervals with p=0.088.

	23°			27℃			31°		
	Weight (g)	Length (mm)	Width (mm)	Weight (g)	Length (mm)	Width (mm)	Weight (g)	Length (mm)	Width (mm)
Initial	0.67	15.290476	8.3095238	0.792941	15.9470588	9.0352941	0.931765	17	9.8176471
Final	0.752917	16.825	8.8625	0.860588	16.7647059	9.0235294	1.117059	19.9235294	10.358824
Total Change in Average Size	0.0829	1.5345	0.5530	0.0676	0.8176	-0.0118	0.1853	2.9235	0.5412

Table 1. Initial measurements of average weight, length, and width per treatment were subtracted from final measurements to obtain the total change in average size according to temperature conditions.

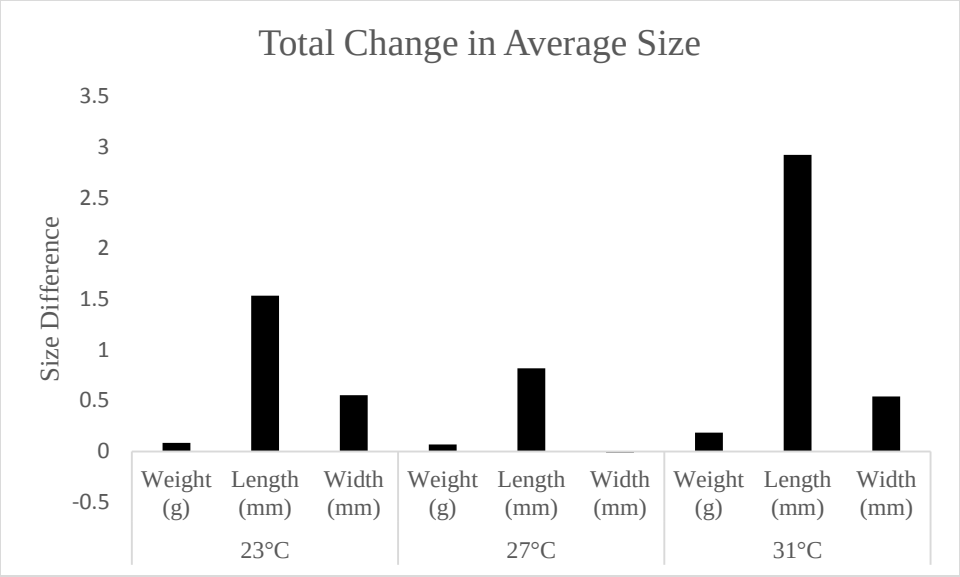

Fig. 3. Total change in average size was calculated by subtracting initial measurements from final measurements per temperature.