Effect of temperature change on the strand size of common eelgrass (*Zostera marina)*

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Abstract

The mean temperature of the Earth has been increasing over the last few centuries as a form of anthropogenic climate change, termed as the 'global warming' phenomenon. This study focuses on the effects of this temperature increase on the morphology of common eelgrass (*Zostera marina*), a coastal seagrass and primary producer that provides nutrients for many aquatic species whose abundance is significantly affected by global warming. The mean global water temperatures between the years 1912 to 2016 were compared to the average strand lengths of 75 samples of *Z. marina* collected from the same time period to determine whether there was a correlation between changes in temperature and *Z. marina* strand size. With a resulting p-value of 0.9067, it was found that there was no significant correlation between *Z. marina* strand length and water temperature fluctuations. Therefore, this study does not contain conclusive evidence that current temperature anomalies are affecting *Z. marina* strand length. However, considering the lack of diversity among the samples' origin and the small sample size in this study, further intensive research is required to determine what impacts future sea temperatures will have on this species.

Introduction

Global climate change is described as a change in mean variables such as temperature as well as an increase in the frequency of extreme events such as heavy precipitation, drought, and heatwaves (Franssen et al., 2011). The ongoing rise in the average temperature of the Earth, termed 'global warming', is caused primarily by the continuous anthropogenic emission of greenhouse gases, such as methane and carbon dioxide, and is influenced to a lesser degree by natural causes such as solar irradiance fluctuations and volcanic eruptions (Ring et al., 2012). While many animal species tend to respond to global warming by migrating to higher latitudes and altitudes, most plants cannot change their geographical location to an area that fits their climatic niche (Daufresne et al., 2009). Hence, plants react more sensitively to environmental stress and must activate resistance mechanisms, such as physiological and morphological adaptations, when optimal temperature limits, 15 °C to 20°C, are exceeded (Nievola et al., 2017; Graiff et al., 2015). Particularly for seagrass species, sea level, salinity, temperature, atmospheric CO_2, and ultraviolet radiation changes can influence their distribution, productivity, and abundance (Short & Neckles, 1999).

The objective of this study was to determine whether there was a correlation between changes in global water temperature and *Zostera marina* strand length, defined for the purpose of this study to be the total combined length of a continuous leaf, root and sheath structure. Also known as common eelgrass, *Z. marina* is a seagrass species that constitutes a significant portion of the diet of many commercial fish species' juveniles, namely Herring, Plaice, and Pollock (Bertelli & Unsworth, 2014). Continuous anthropogenic impacts such as habitat destruction, eutrophication, pollution, and overharvesting have contributed greatly to the effects of climate change, decreasing the resilience of coastal region ecosystems and putting temperate coastal populations of *Z. marina* at risk (Ehlers et al., 2008). Moreover, some studies suggest that water temperatures above the range of 25°C - 28°C cause mortality in *Z. marina* populations (Ehlers et al., 2008). Previous studies conducted under short time spans of a few weeks have found a negative correlation between increased temperature and *Z. marina* growth rate in culture-experiments (Hammer et al., 2018; Nejrup & Pedersen, 2008). These findings align with the fact that, due to *Z. marina's* intrinsic variability, its leaf morphology differs among ecotypes and seasonal cycles (Backman, 1991). However, the long-term effect of increased temperature on *Z. marina* strand size in the perspective of climate change has not been verified. To establish whether there is a relationship between average global temperature and the mean strand length of *Z. marina* across several decades, images of *Z. marina* samples were collected from an online specimen database. The measured average lengths of the samples were then tested for correlation with global average temperature records over the past century. The findings of this study aim to provide further insight to the effects of climate change on seagrass.

Methods

Data Sources:

Data on *Zostera marina* was collected remotely from the Consortium of Pacific Northwest Herbaria (CPNWH) website with years of collection ranging from 1912 to 2016. Only samples that included an image were used in this study and a total of 75 samples of *Z. marina* were analyzed. Out of all 75 samples, 72 were collected from aquatic habitats in North America, including the countries USA and Canada. Only 3 samples were collected from Eastern Europe, including the countries Russia and Finland. To reduce possible biases towards decades with significantly more available samples, samples were randomly excluded to yield a maximum of 10 samples per decade. The sample exclusion process was done using a random number generator. Only 3 samples were collected from the 1920 to 1960 period. Data on average global sea temperature anomalies were retrieved from the National Oceanic and Atmospheric Administration website and included temperature data for the 1912 to 2016 CE period.

Data Collection:

Data analysis was done using ImageJ version 13.0.6. Once the image of each sample was opened, a 1-100 numbered printed grid was overlaid on top of the image, and using a random number generator, three random numbers were produced to locate three strands to be measured (Figure 1). The random number generator was refreshed if the initial number did not correspond to a strand on the image. Once strands were chosen, the segmented line tool in ImageJ was used to measure the strands starting from the sheath to the root. The measured strand length was then converted to centimeters using the image scale bar. The mean of the three strands was then calculated to represent one data point.

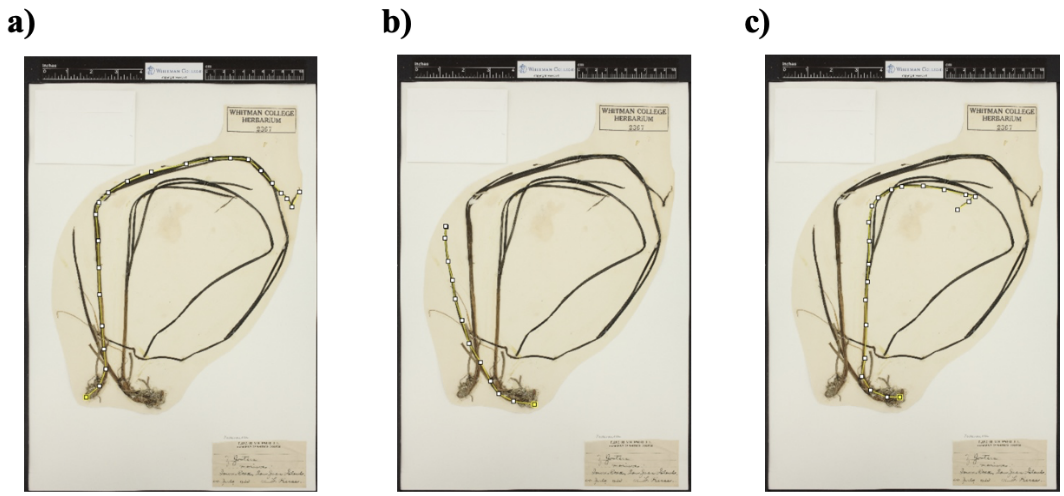

Figure 1. The segmented line tool used to measure the strands of one *Z. marina* sample in ImageJ. Panels a, b, and c represent the measurements taken for three different strands.

Statistical Analysis:

To test for a correlation between *Z. marina* strand length and global sea temperature anomalies, we performed a Pearson's correlation test using GraphPad Prism version 9.3.0. The data on strand length was also log transformed to exhibit a more normal distribution. The significance level was set to 0.05.

Results

The results of a Pearson correlation test showed there to be no significant correlation between average strand length of *Zostera marina* collected in different years and global sea temperature anomalies of the corresponding year (Figure 2 & 3). Temperature anomalies represent the global sea temperatures relative to the 1971 - 2000 time period. The test showed the p-value to be 0.9067 and the R^2 value to be 0.0001919. Among the data, the minimum measured average strand length was 6.644 cm and the maximum was 108.073 cm.

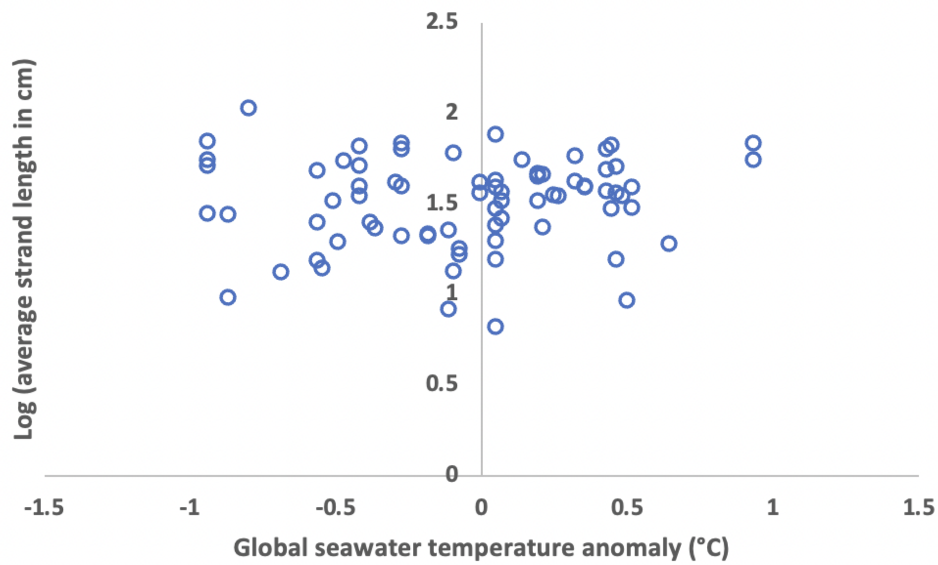

Figure 2. The relationship between log of average strand length of *Zostera marina* and global sea temperature anomalies at year of collection. Temperature anomaly represents the global sea temperature relative to 1971-2000 average temperatures. Positive anomalies represent increases in temperature compared to the 1971-2000 average temperatures and negative anomalies represent decreases in temperatures compared to that period. Each data point represents the log of the average of three strands measured for one *Z. marina* sample. Sample size: N=74. The Pearson correlation test showed that there is no significant correlation (p-value= 0.9067 and R^2 = 0.0001919).

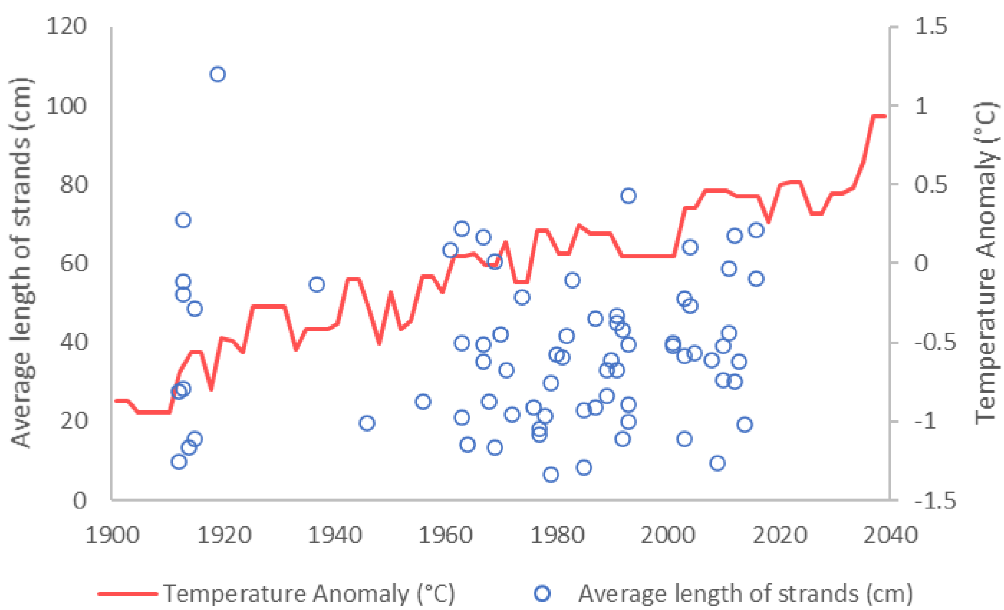

Figure 3. The relationship between average strand length of *Zostera marina* and the year of collection with an overlay of the average global sea temperature anomalies. Temperature anomalies are determined relative to the average temperatures of the 1971-2000 period where

positive values represent increases in temperatures compared to that period and negative values represent decreases in temperatures. Average length of strands were calculated by taking the mean of three strand lengths for a single sample.

We observed that many samples taken from earlier years between 1920 - 1990 were fragmented and incomplete, while samples collected in later years were well-preserved. We also observed a substantial variety in the strand sizes of different samples within each decade.

Discussion

As global temperatures rise, conditions become alarming and possibly devastating for living organisms around the earth. Many species attempt to adapt to these changes, while many exhibit changes in phenotype, such as size or colour. The change in length of the leaf, sheath, and root in *Z. marina* over different water temperatures are generally conclusive in literature. Many studies agreed that strand length of *Z. marina* reached its maximum when grown at temperatures 15-20°C, with survival rate drastically dropping after 25-28°C (Niu et al., 2016; Zhou et al., 2015; Xu et al., 2016). Until global water temperatures rise to this limit, *Z. marina* may be yet to exhibit drastic changes in length. The increase of biomass in *Z. marina* is strongly correlated to water temperatures (Ok et al., 2013), but research has also found significant factors that affect the strand length of *Z. marina*, such as salinity, irradiance, and water clarity (Xu et al., 2016; Kim et al., 2018; Shields et al., 2018). These previous experiments on *Z. marina* were conducted in a controlled laboratory setting under shorter time spans, unlike the diverse samples collected from the wild for over a century used for our data.

Our study found no significant correlation ($p > 0.05$) between the change of strand length and global temperature, which can be accounted for by several methodical limitations. Firstly, the samples obtained mostly originated from the West Coast of the United States and Canada (73 samples out of 75), however *Z. marina* is found throughout not only North America but Europe and Asia as well (Blok et al., 2018). Therefore, the diversity of the samples was limited, meaning the population was not well represented. Further, the sample size of *Z. marina* (n = 75) analyzed was small in relation to the scale of the study. The study length also ranged from a short period of time (1912-2016) compared to how long it takes to see significant climate change effects on a species. The impact of this factor is further seen as there were a limited number of samples from the 1920-1960 period, wherein only three samples could be acquired. While the study used a maximum of 10 samples per decade, some periods only had one sample per decade (1930's, 1940's and 1950's), meanwhile the 1920's had no samples available. As a result, most of the study's findings focus on samples from 1961-2016. Moreover, the measurement of samples was affected as *Z. marina* obtained from 1920-1990 were not as well preserved and instead were more fragmented compared to the samples from 2000-2016 which could skew the results. Possible human sources of error could have been made during the study as well. For example, five individuals took measurements of the *Z. marina* samples, which could cause slight variation in the results as strand lengths were obtained by tracing a line on the images of *Z. marina* samples, and the image scale bar to calculate the real length. Individual precision with the measurement tool program could have affected the calculated real length of *Z. marina* strands. Due to these factors, the findings of our study may not be as accurate and representative of the *Z. marina* population. Further studies may confirm a correlation, or lack thereof, between water temperature anomalies and average strand length in *Z. marina.*

Conclusion

With climate change being a key global issue, it is important to address how rises in temperature impact the ecosystem and in particular *Zostera marina*, otherwise known as common eelgrass, as they are a critical food source for many fish species. Overall, a significant difference between *Z. marina* strand length and temperature was not found in the study. As a result, the study can not lend evidence to temperature effects on *Z. marina*. For future research, it is important to further investigate the impact of temperature on *Z. marina* samples from the early 1900's if available to provide more evidence for climate change effects on *Z. marina* strand length.

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