Sea Sponge Respiration Rate and its Connection to Water Temperature

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Abstract:

Sea sponges are incredibly important foundational species in marine ecosystems. They provide habitat and food for several organisms and fix important resources like nitrogen and phosphorus. They also aid in cleaning the water by feeding on marine bacteria and viruses. However, with warming oceans due to anthropogenic climate change, the future success of sea sponges is of major concern to researchers. To test sea sponge adaptability in the higher temperature oceans the local San Juan Island *Myxilla incrustan* sponge had its oxygen intake compared at both ends of the International Panel on Climate Change's (IPCC) projected temperature changes in the ocean, those being 2° C warmer and 4° C warmer. This paper is then testing the hypothesis that sea sponges would show a change in their oxygen consumption with different temperatures. After experimenting, statistical tests found that there was no significance between oxygen consumption and the different water temperatures. This disagrees with other published material and is likely due to a lack of gathered data and or possible flaws with this studies experimental design. If sponges cannot adapt to warmer oceans then a large foundational species will decline in abundance due to lower available oxygen to grow, reproduce, etc. Majorly impacting established marine ecosystem dynamics. On the other hand, if sea sponges can adapt, as showcased by various published materials, to the higher water temperatures by increasing their respiratory rate then the environments where sea sponges reside could have reduced dissolved oxygen, leading to many populations of marine organisms reducing their activity. No matter which scenario occurs, warming oceans will have an impact on sea sponge populations and the important ecological niches they fill. To prevent these detrimental changes the major sources of anthropogenic climate change must be mitigated or managed in some way to aid in preventing the major impact that warmer waters will have on sea sponges and the ecosystems they reside in.

Introduction:

Sea sponges are incredibly abundant and one of the oldest living successful suspension feeders in marine ecosystems. Their high water filtration rate aids in the removal of bacteria and viruses from the water column (*McMurray et. al 2016)*, and many contain photosynthetically active cyanobacteria which assist in providing resources to the local ecosystem. (*Wilkinson, Clive 1988).* Sponge also provides habitat for several marine organisms (*Hogg et al. 2010),* and fixes nitrogen and phosphorus for marine habitats (*Maldonado et al., 2024).* However, with increasing ocean temperatures due to anthropogenic climate change the success of many sea sponge species, and the ecosystems they reside in, is in question. If sponges can adapt to the high water temperatures and high metabolic stress it could mean a lack of space for other critical species and a reduced amount of dissolved oxygen available to be utilized by other organisms (*Wulff, 2006).* If they cannot adapt, a major source of natural marine filtration (*Peterson et al. 2006*) and food supply (*Archer et al. 2020)* could struggle to survive leading to global ecosystem destabilization. This study hypothesizes that warmer waters caused by climate change will cause a change in oxygen consumption in sea sponges.

To test the influence of warming waters on sponge respiration a common Pacific Northwest sea sponge, *Myxilla incrustans,* was collected and exposed to warmer waters to measure if the sponge would change its oxygen intake rate. The warmer water temperatures were based on the Intergovernmental Panel on Climate Change (IPCC, 2014) projection that the ocean temperature will increase in the range of two degrees Celsius to four degrees Celsius by the year 2050. By comparing sponge oxygen intake at two different temperatures this study will attempt

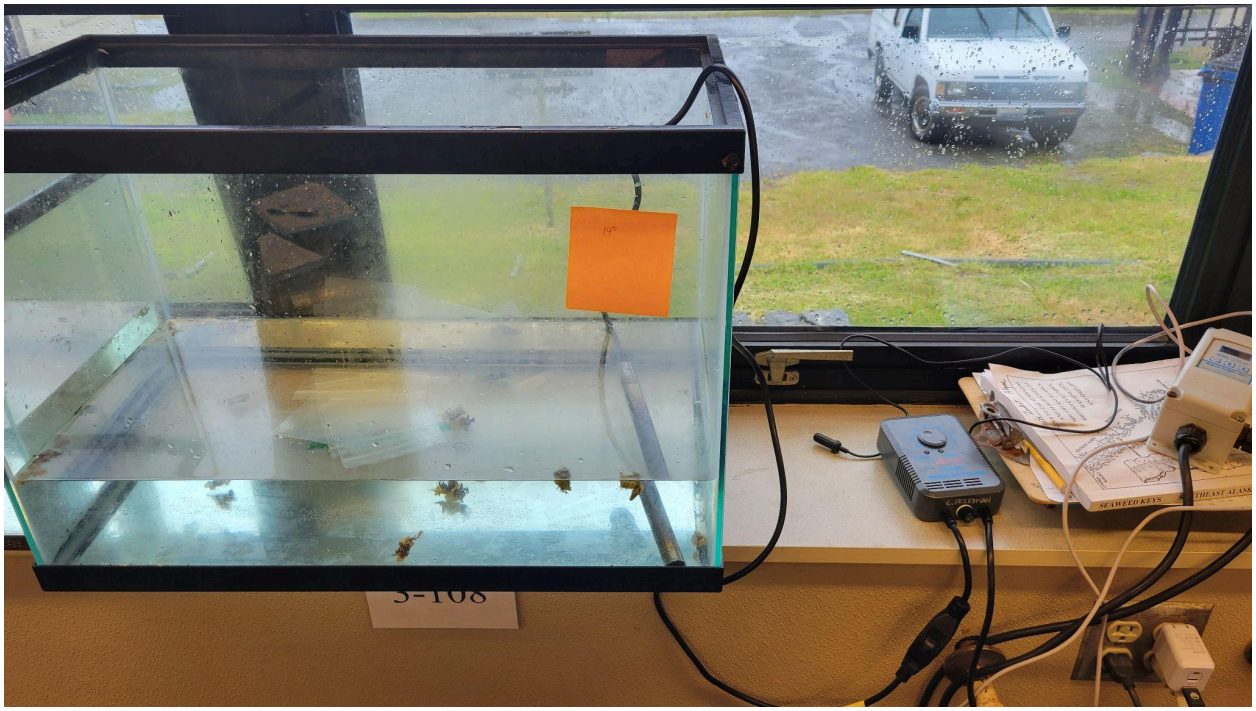
to assess how sponge respiration may be influenced by climate change, and will discuss how this may impact marine ecosystem dynamics where sea sponges are present.

Methods:

Organism collection was performed at the dock at the Friday Harbor Labs (FHL) in the San Juan Islands (48.545953, -123.011899), collected specimens have been utilized in sponge testing before such as in the study, "*Oxygen consumption by a coral reef sponge." (Hadas et al. 2008)*. The tires attached to the FHL dock provided the opportunity to acquire *M. incrustans* for my temperature tests. On two separate occasions between the hours of 12 PM to 4 PM on the dates of May 15th and May 16th, 2024 a wooden rod was then used to lift the dock tires out of the ocean. *M. incrustans* was scraped off the tires with a utensil and placed inside a bucket with seawater. 200g of wet sponge mass in total was collected from the sampling site and used in the experiment. After collection, sponge specimens were then temporarily housed in sea tables with a constant flow of ambient seawater for their nutritional and respiratory needs, this stage is similar across sponge studies including the research, "*Suspension feeding in marine sponges Halichondria panicea and Haliclona urceolus: effects of temperature on filtration rate and energy cost of pumping." (Riisgard et al. 1998)*. They were then allowed time to destress and acclimate according to a similar strategy utilized by the study "*Interactive effects of temperature and pCO 2 on sponges: from the cradle to the grave." (Bennet et al. 2017)* In their study, they allowed the sponge a 4-week acclimation period, but due to time restraints, 2 days was used in this experiment.

Three 45-gallon aquarium tanks were utilized during the testing phase and an equal amount of seawater, 40L, from the sea tables was added to each. The two increased temperature tanks were attached with a thermometer and titanium 25W heaters. A *Finnex* HC-0800 heater controller allowed for specified temperatures to be selected. The ambient sea temperature on the day of testing was 12° C, meaning the two heated tanks were set to 14 degrees and 16 degrees respectively. The second day of testing had a lower starting DO content, around 4.3 mg/L, and the ambient seawater was slightly colder at 11° C. A small aluminum foil weigh boat and a tared scale of 33g of wet sponge mass, following a similar weight used by *Peterson et al.*, were

weighed and added to each of the three tanks. Before the sponge was added to each tank a baseline dissolved oxygen content (mg/L) was taken, after these readings were collected the weighed *M. incrustan* masses were added to each tank.



Every ten minutes for 100 minutes using a YSI PRO 2030 handheld dissolved oxygen meter the current oxygen content for each tank was recorded, with a short duration required for the oxygen meter to remain at a constant value. After every oxygen reading, the tanks were stirred with a spoon to ensure the sponge received water flow. After the 100-minute testing phase, the sponge masses were returned to their sea table to be returned to the ocean later. A total of two, 100-minute trials were performed, organism issues and tank troubles restricted the amount of testing able to be performed. After the testing phase had ended the collected data points were added to a Microsoft Excel spreadsheet. To showcase the difference in total dissolved oxygen consumption between temperature treatments the final dissolved oxygen contents were compared and averaged between the two trials performed and significance will be determined with a one-way ANOVA statistical test. To analyze the possible difference in oxygen consumption rates between temperatures the final oxygen content was divided by the length of the experiment, 100 minutes, and the mean rates for each temperature treatment were also compared with a one-way ANOVA test.

Results:

Overall, the oxygen consistently declined in all three temperature treatments throughout both trials during the study period. In the first trial, the tank with a 16° C temperature had the fastest dissolved oxygen (DO) consumption at a rate of 0.0247 (mg/L)/min and ended with the lowest concentration, 4.06 mg/L. The second trial is being presented separately here due to different ambient water conditions. The second trial seawater had a lower starting temperature

and lower starting DO, occurred the next day and had a lower starting DO concentration of 4.55 and a lower starting temperature of 11° C. The ambient temperature tank had the lowest ending DO compared to the first trial.

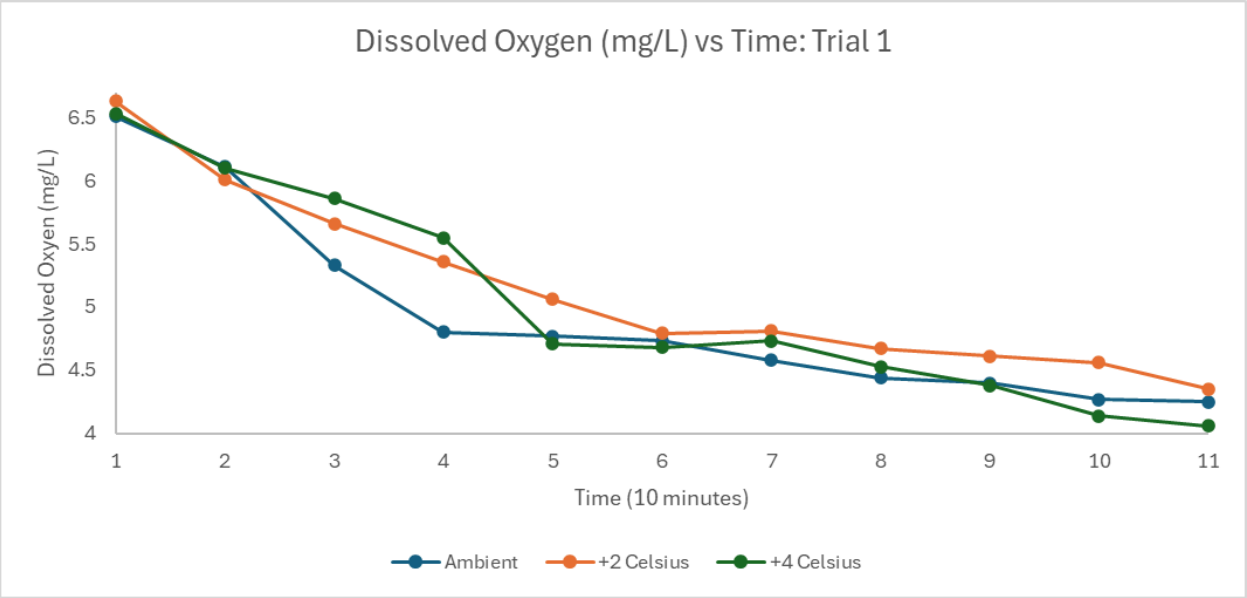


Figure 1: Graph showcasing the amount of dissolved oxygen (mg/L) present in each 40 L tank during the first trial's time frame (100 minutes). Each tank contained 33g of M. incrustans sea sponge. The blue line shows the DO content of the ambient tank (12C), the orange line shows the DO content of the 2-degree warmer tank (14°C), and the green line shows the DO content of the 4-degree warmer tank (16°C) over the observation period. Each time unit represents 10 minutes with 1 on the x-axis being 0 min.

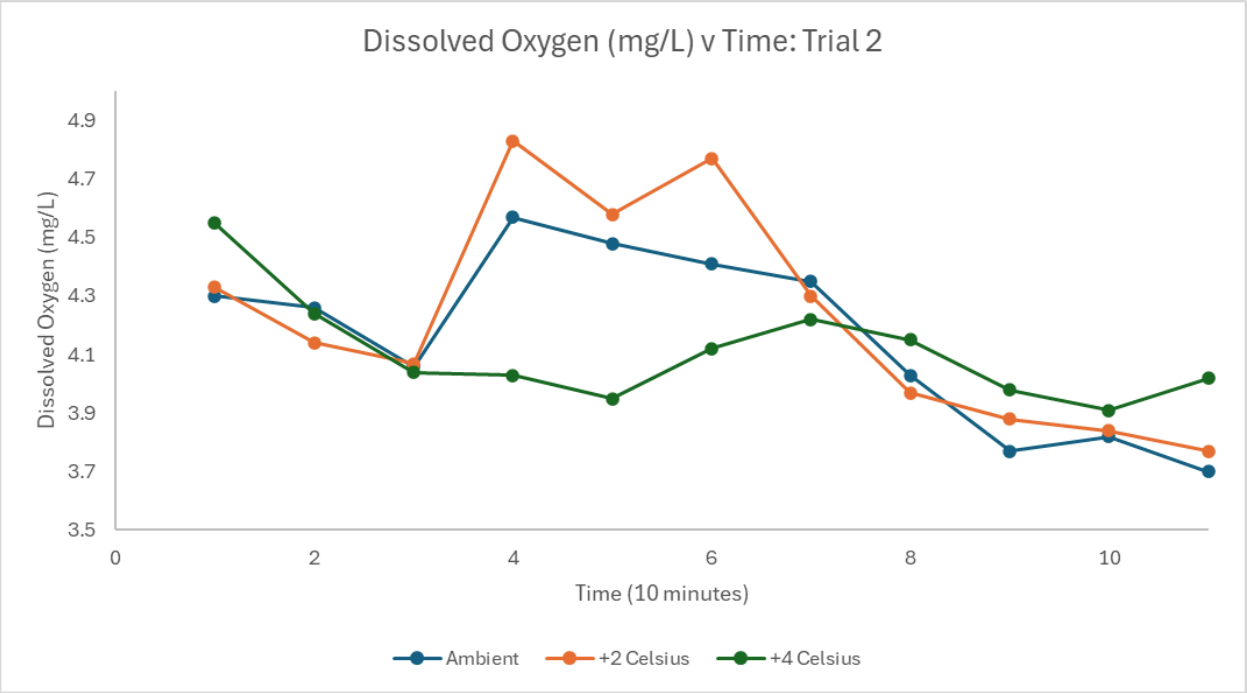


Figure 2: Graph showing the decline in dissolved oxygen content (mg/L) in the 3 modified temperature 40L tanks over the observation period (100 minutes). Each tank contained 33g of M. incrustans sea sponge. The blue line shows the DO content of the ambient temperature, 11° C, tank, the orange line shows the DO content of the 2-degree warmer tank (13 C), and the green line shows the DO content of the 4-degree warmer tank (15 C) Each time unit represents 10 minutes with the 1 on the x-axis being 0 minutes.

After comparing the final DO content of each tank in both trials and averaging the values together we can see in Figure 3 that there seems to be little evidence of a pattern between temperature and the final amount of dissolved oxygen present in the tanks after 100 minutes. A one-way ANOVA test performed in Microsoft Excel confirms this with a p-value of 0.96, meaning there is a 96% chance the pattern witnessed was due to chance.

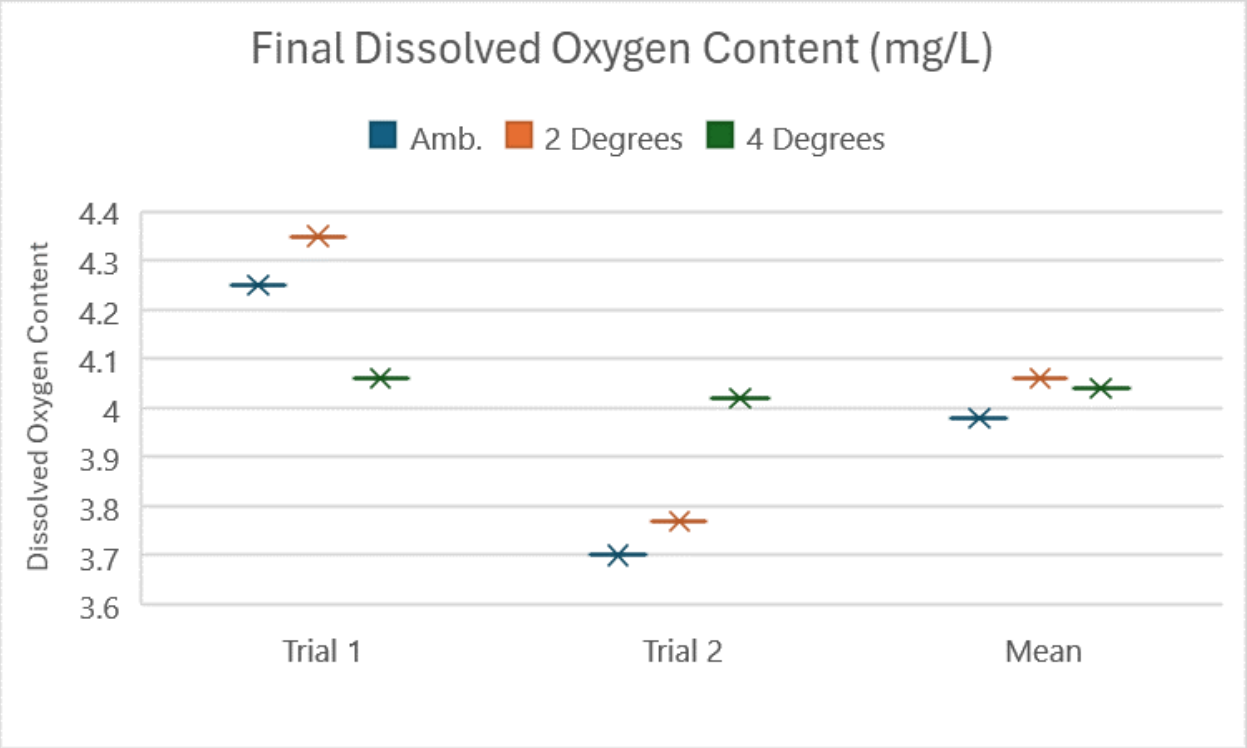


Figure 3: Graph showing the distribution of the final dissolved oxygen content in each of the three temperature-controlled 40L tanks, Ambient seawater (blue), 2 degrees warmer (orange), and 4 degrees warmer (green) in trials 1 and 2, and their mean values. Each tank contained 33g of M. incrustans.

Finally, by subtracting the starting DO from the final DO in each tank and dividing it by the observation time of 100 minutes we can obtain the *M. incrustans* oxygen consumption rate in each selected temperature. Figure 4 showcases that on Trial 1 the 4-degree warmer tank (16° C) had a higher amount of DO consumption compared to the other two tanks, but in Trial 2 there is little to no difference between treatments. When averaging the consumption rate between both trials we can see that the mean consumption in the 4 degrees warmer tank was slightly higher than the other two tanks. However, after performing a one-way ANOVA test in Excel the provided p-value of 0.99 means that in this experiment there was no significant difference between temperature and *M. incrustans* respiration rate.

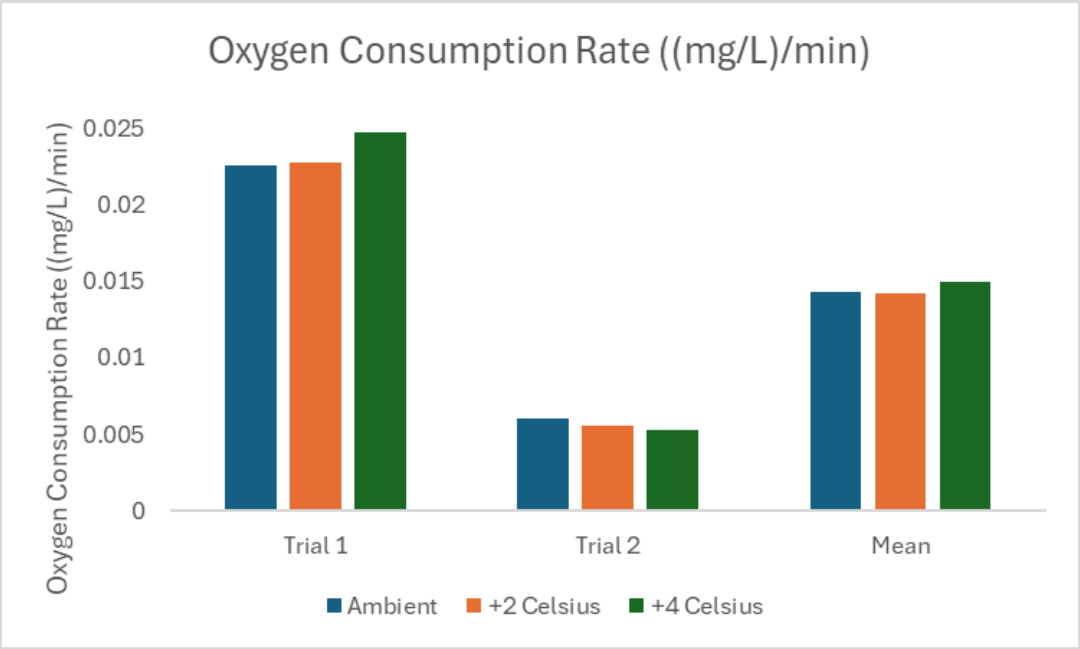


Figure 4: A bar chart showcasing the difference in oxygen consumption rates between the temperature-controlled 40L tanks in both trials and the mean rate for the three different temps, ambient (blue), 2 degrees Celsius warmer (orange), and 4 degrees Celsius warmer (green).

Discussion:

Due to the high p-values when comparing final DO content and DO consumption rate, we accept the null hypothesis for my experiment that temperature has no significant impact on *M. incrustans* respiration rate. This disagrees with other similar studies on sponge respiration and its connection with temperature such as the research paper, *"The response of a boreal deep-sea sponge holobiont to acute thermal stress."* (*Strand et al. 2017),* which provided a significant connection ($p < 0.001$) between respiration rates and elevated temperatures. Another study inspecting the connection between sponge respiration and temperature created by *Strano et al.* found a p-value of 0.0001, showcasing a strong positive relationship between temperature and sponge respiration. These studies prove the connection is present in nature, but due to several complications in my experiment, the phenomenon was not observed in the research. There are many possible explanations for why we did not witness the documented relationship in this study. One of them is due to a lack of trials and raw collected data points. Tank issues like flow being turned off, and the sea tables overflowing also played a hand in reducing data collection time. Organism housing problems also played a factor as my sponge specimens died multiple times before experimentation could begin. Due to these factors, there was a lack of availability in the schedule to collect as much data as preferred, with more data the significance may have been present in my dataset with a lower p-value.

Another reason the connection between respiration and temperature was not observed is likely due to issues with the experimental design or lack of control over non-experimental variables. The tanks used were open to the air which may have caused slower oxygen consumption than closed-off tanks due to oxygen flowing into the water from the open air. The temperature may have decreased over time due to heat passively entering the seawater from the

warmer room, reducing the heat stress the sponges were purposely placed under and reducing the connection strength between sponge respiration and temperature. The tanks with modified temperatures had little water flow to more easily see oxygen declines. *M. incrustans*, which reside in high wave action areas, may have had lowered respiration in the sitting water inside the tanks. The final issue that may have caused the lack of significance is because of the duration of the experiment. The observation time was set only for 100 minutes while other studies, such as "*The response of a boreal deep-sea sponge holobiont to acute thermal stress*" (*Strand et al. 2017)*, had the sponges in elevated temperatures for 14 days. The sponges may not have had enough time to adapt their respiration to the high temperatures, explaining the possible lack of significance.

To improve the experimental design it should be ensured that the tested temperatures for the tanks were constant during the observation period. The observation period should also increase from 100 minutes to something closer to the observation time of the study, "*The response of a boreal deep-sea sponge holobiont to acute thermal stress*." (*Strand, et al. 2017)*, ideally 3 to 14 days long to fully witness the changes in respiration rates. Overall, having more control, through better design or better technology, over non-experimental variables will allow the results of the observational study to be more accurate to the studied relationship present in nature.

However, assuming that my results are accurate would mean that sea sponges cannot adapt to increased oxygen demands due to higher water temperatures. This would mean that a vital foundation species that provide habitat for organisms and provides nutrition for others in many marine ecosystems would struggle and likely decline in abundance due to lower available oxygen with the increasing sea temperatures. (*Archer et al. 2020)* Sea sponges are important natural water filterers by aiding in the removal of bacteria and viruses in the ocean by feeding on them (*Peterson et al.)*. Sponge removal would mean a drastic decrease in ocean health by allowing marine bacteria and virus populations to increase due to reduced predation by sponge filtration as shown in the study *"Sponge species richness and abundance as indicators of mangrove epibenthic community health." (Diaz et al. 2004)*. Sea sponges also provide spatial competition and without them many species would overgrow, changing ecosystem dynamics as documented by the research paper "*Sponges as agents of biological disturbance*". (*Bell, James. J, 2008)*

On the other hand, if sea sponges can adapt to the higher temperatures as shown in "*Sponge physiology and function in a changing ocean" (Bates*, *Tracey Elaine Mary, 2015)* then their oxygen intake will increase with the sea temperature. This will cause the dissolved oxygen in the marine ecosystems with sea sponges present, which is a majority, to drop reducing the amount of activity of many marine organisms (*Shi et al 2021)*. This will cause several organisms to have less available oxygen to move, feed, and grow. Meaning that in the newly warming oceans sea sponges are out-competing most sessile organisms in the ocean. By studying this impact more closely we can see just how successful sea sponges will become and the ecological impacts their success will have on the future oceans.

Either scenario for sea sponges spells out drastic changes in marine ecosystems as climate change continues to warm our seas. To prevent these far-reaching alterations to marine systems action must be taken to immediately mitigate the largest contributors to anthropogenic climate change to prevent the harshest of ecosystem impacts from occurring.

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