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Are Q_{10}s of more than 1,000, as reported for Antarctic seabed's fauna, realistic?

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1 Summary

Recently Ashton et al. [2] describe the results of what they call the first ever experiment in which benthic assemblages are warmed to ecologically relevant levels in situ. West of the Antarctic peninsula, they employed heated settlement panels and studied the settlement and growth of pioneering species over a 5-months period at ambient temperature and at 1 °C and 2 °C above ambient. Such temperature increases are expected within the next 50-100 years. They claim that the two most dominant species doubled their growth rate already at an increase of 1 °C. They further state that this implies Q10s around 1,000, which is much higher than anticipated. This unpredicted result should, according to the authors, critically change our thinking of how polar communities might respond to ocean warming. Indeed, such extreme Q_{10}s are a surprising result, and not in accordance with more than a century of laboratory research or field research in temperate zones. Here I will, however, show that the claim is unsubstantiated and that the observed in situ growth rate response to temperature of these Antarctic species is much weaker than claimed, and not very different from previous work in the temperate zone.

2 Instantaneous instead of absolute growth rate

Ashton et al. observed that the area covered by a single colony of a spatially dominant bryozoan species (*Fenestrulina rugula*) or a single individual of a spirorbid species (*Romanchella perrieri*) is already after a few months twice as high in the +1 °C treatment compared to the ambient temperature control. Their figure 2A upper panel, for example, shows that the area covered by a bryozoan colony after 5 months has a median value of 32 mm^2 in the +1 °C treatment, and only 14 mm^2 in the control. They used the absolute change in radius as a measure of growth and concluded that growth rates doubled at an increase of +1 °C. One should however realize that the ratio between the absolute areas covered in the two treatments (or the ratio between the absolute change in radius) does not say anything about the difference in growth rates. It can be easily shown that the ratio in area covered by two exponentially growing individuals or colonies (with the same initial area) is given by $A_1/A_2 = \exp((r_1 - r_2)t)$, and will thus in the long run become infinitely large, even if the difference in instantaneous growth rates r_1 and r_2 is extremely small. The same holds of course for the ratio in absolute growth rates $r_1A_1/(r_2A_2)$. It can also be easily shown that two individuals who have exactly the same instantaneous growth rate show a consistent difference in size when one of the individuals starts to grow somewhat earlier than the other. Compare, for example, the sequences $1, 2, 4, 8, 16, 32, 64$ and $1, 1, 2, 4, 8, 16, 32$, in which one individual is consistently (apart from the first period) twice as big as the other. They both double in size per time period and thus have the same growth rate, but the second species has a lag of one time period.

Similar things are also observed in the Ashton et al. study. Plotting for each settlement panel the natural logarithm of the mean area covered by a single colony or individual (Fig. 1a and 1c) immediately shows that the instantaneous growth rates do not differ dramatically among treatments. Note that the slope of each linear section in such plot represents the instantaneous growth rate. Further inspection shows that generally the growth rate levels off with increasing size, with the exception of a much slower growth during the first period of the bryozoan colonies at ambient temperature. Apparently they have a delay in the start of the growth period. This is even better illustrated in a plot of the instantaneous growth rate ($\log(A_{i+1}/A_i)$ in 1/month) versus the geometric mean size (Fig. 1b). If the maximum instantaneous growth rate of the bryozoan colonies (which is obtained in the first period for the +1 °C treatment, but in the second period for the ambient temperature) are compared, one arrives at a factor of 1.24 (i.e. 1.81/1.46). This is slightly higher than the initial expectation of an increase of 12-17% of the authors, but much lower than a factor 2. An increase with 24% at +1 °C implies a Q_{10} of 8.6. This is a large value, but far away from the reported value of 1,000, and in line with previous research on the temperature dependence of bryozoan growth. For example, Amui-Vedel et al. [1], who studied bryozoan colony growth in the UK reported a doubling of the instantaneous growth rate at an increase of +4 °C, from 14 °C to 18 °C, which means a Q_{10} of 5.7. The temperature effect for the spirorbid species in the Ashton et al. study is in the same order of magnitude (Fig. 1c and 1d).

Hence the conclusion of the Ashton et al. study should have been that increasing temperatures may cause an earlier start of the growth period and an increase in the growth rate that is in accordance with previous studies in temperate zones. Experiments as performed by Ashton et al. are very interesting and important for understanding the impact of climate change in the Antarctic realm. The study deserves follow-up experiments, but one should take care that appropriate methods of analysis are used.

3 Acknowledgments

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References

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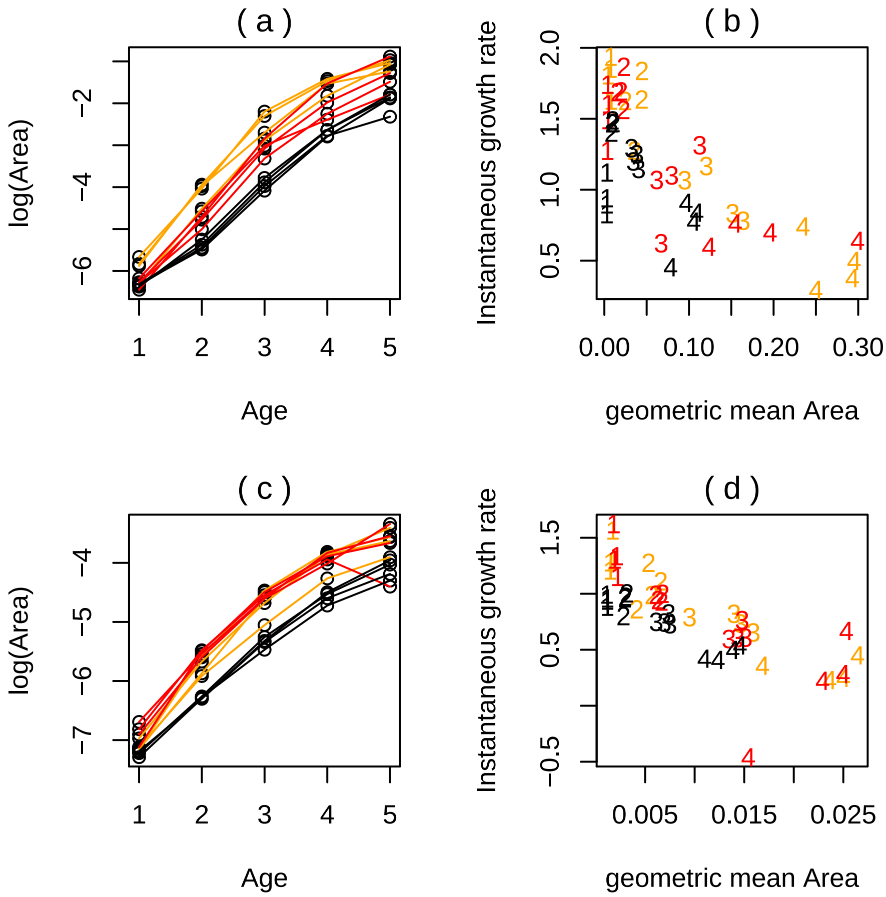

Figure 1: (a,c) Natural logarithm of the mean area (cm^2) per colony or individual versus age (months); (b,d) Instantaneous growth rate (1/month) versus geometric mean area (cm^2). Upper panels (a,b) refer to colonies of the bryozoan species *F. rugula*, lower panels (c,d) to individuals of the spirorbid *R. perrieri*. Each line or dot refers to a settlement panel; black refers to the ambient temperature, orange to the +1 °C, and red to the +2 °C treatment; numbers in the right panels refer to the time period.