INSIDE JEB

Mussels cope best when the going gets hot fast

California mussels on the shore beneath the Hopkins Marine Station.
Photo credit: Luc Moyen

It's hard to deny; the planet is warming and it's getting hotter faster. According to the UK Meteorological Office, the top 10 warmest years on record have all occurred since 2002. Increasing temperatures have a powerful effect on cold-blooded (ectothermic) creatures and many immobile creatures – such as mussels (e.g. *Mytilus californianus*), which reside on the seashore – may be particularly vulnerable. Nicole Moyen, George Somero and Mark Denny from Stanford University, USA, explain that mussels that make their homes at different locations on the shore are likely to heat up at different rates, with animals that are more exposed in locations higher up the beach warming faster than those lower down the intertidal zone. But it wasn't clear how much of a toll different heating rates take on high and dry molluscs. Knowing that mussel hearts speed up as the temperature rises until they give out when it gets too hot just before the molluscs die, Moyen and her colleagues realised that they could monitor when the mussels' hearts fail to tell them when the molluscs were getting into trouble as they warmed at different rates.

Collecting *M. californianus* from the high and low tide zones on the beach outside Stanford University's Hopkins Marine Station, Moyen fitted each of the molluscs with a temperature sensor and infrared heart rate monitor to record how their heart rates changed as she warmed them at rates ranging from 3 to 8°C h^{-1}. Impressively, the mussels that came from higher up the shore coped better than those that spent more time immersed in water lower down the beach. The high-tide mussels' heart rate dropped rapidly at ∼37°C when the temperature rose slowly. However, their hearts held out better as they heated up faster, only failing when their body temperature reached ∼39°C. The mussels that survived near the high-tide line were well equipped to survive the faster heating rates that they encounter when the sea is out.

In contrast, the mussels from lower down the shore struggled. Their hearts slowed suddenly at a cooler ∼36°C when the air was heated at the fastest rate and only coped up to ∼35°C when warming at the slowest rate. It didn't seem to matter how fast the low-tide mussels warmed up; they got into trouble at lower temperatures than the more robust mussels from higher up the beach.

The team suspects that the mussels that spend the most time exposed to the sun as the tide goes out cope better than those that are further down the beach because they experience faster heating rates routinely. 'We hypothesise that there are likely cellular and molecular changes allowing for the high-zone mussels' improved cardiac thermal tolerance at faster heating rates', they say. And the trio warns that researchers hoping to understand how mussels and other ectotherms may cope in a warming world would be wise to recreate the temperature fluctuations experienced by creatures in their natural homes when testing their ability to endure high temperatures in the lab. 'It is important that the effects of heating rates and acclimatisation are taken into consideration in ecological models predicting mussel survivability and hence intertidal community ecology', they say.

10.1242/jeb.212019

Moyen, N. E., Somero, G. N. and Denny, M. W. (2019). Impact of heating rate on cardiac thermal tolerance in the California mussel, *Mytilus californianus*. *J. Exp. Biol.* **222**, jeb203166. doi:10.1242/jeb.203166

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