Can lizards beat the heat, or will they go extinct?

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Global change due to anthropogenic effects over the last century is one of the greatest threats to biodiversity and ecosystem functioning that we currently face. While the planet has experienced (and recovered from) several phases of mass extinctions and associated global ecosystem shifts, none of these, as far as we know, have been the result of overexploitation by a single species. The negative effects on biodiversity come in a myriad of shapes and sizes,[1] but the most acute are habitat loss, alien invasive species and accelerated climate change.[2,3,4]

Despite critical gaps in the understanding of these ultimate effects, it is theoretically possible to quantify and catalogue the proximate effects of the first two. For example, 3% of global forest cover has been lost in just the last five years.[5] By the turn of the 21st century, nearly 10% of South Africa's land surface had been invaded by more than 180 species of exotic plants.[6] These figures provide an estimate of the negative impacts on biodiversity. The numbers are disconcerting to the informed, unbelievable to the uninformed and unimportant to the millions who are without modern conveniences and ample resources at their fingertips. But the negative impacts of 'climate change' on biodiversity are unknown. While climate change itself is quantifiable, a fact that has been readily shown by the multitude of graphs documenting rising temperatures over the last 50 years, it is difficult to 'see' the negative effects of climate change on biodiversity and, therefore, until recently, it has been difficult to accept that this change is damaging.

A recent article[7] not only shows that climate change already has affected our planet's biodiversity, but may provide a way forward for predicting the threats. In their paper, Sinervo et al.[7] show that a number of populations from several species of *Sceloporus* lizards have become locally extinct in Mexico. Long-term datasets allow them to make this assessment by comparing lizard absence/presence at 200 sites since the mid-1970s. They found that *Sceloporus* lizards are now locally extinct at 12% of the sites, although, for some species, they found range expansions into these same sites where they previously did not occur. While other aspects of global change could cause such extinctions (e.g. habitat destruction), in this case it appears that air temperature increases over the past 35 years is the cause.

Lizards are ectotherms and many species bask to obtain active body temperatures (T_b). They balance this against their critical thermal maximum (CT_{max}), which is the temperature at which overheating results in death. Thus, they must maintain T_b without reaching CT_{max} by either basking to warm up, or retreating into the shade to cool down. Sinervo et al.[7] show that air temperature in winter and spring has increased dramatically at their Mexican study sites, meaning that *Sceloporus* lizards must retreat to the shade more often in order to avoid reaching CT_{max}. The trade-off is that they then lose out on valuable foraging time, the effect of which is greatest during the spring breeding season. Sites in which activity time (h_r) has been reduced to less than 4 h per day are the same sites in which populations have become locally extinct. Sinervo et al.[7] have managed to establish a strong link between rising temperatures and the degree of

Source: Photo taken by John Measey
Cordylus polyzonous **(family *Cordylidae*) basks on a rock at Rooipoort Nature Reserve near Kimberly, South Africa**

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local extinction and have shown that, where lizards are already close to thermal limits, small increases in temperature produce negative effects. Even if climate change does not proceed at the alarming rates that have been forecast, this rise in temperature, over just a few decades, already has produced astonishingly rapid population-level responses. In fact, Sinervo et al.[7] predict that nearly 60% of *Sceloporus* lizard species will be extinct by 2080.

These authors[7] then make a case for a global model that can be built on their original observations and, by incorporating T_b into their model, they predict the geographic regions and species that are most vulnerable because of a reduction in h_r. Bill Branch of the Port Elizabeth Museum, a co-author on the study, assisted by including data from the *Cordylidae*, a family of rock-dwelling African endemic lizards. According to Branch, the addition of *Cordylidae* was valuable because it allowed an assessment of species that are rock dwelling, the significance of which is that rocks are a type of substrate that can heat rapidly and cool slowly. *Cordylidae* could thus be imperilled by temperature increases sooner than ground-dwelling or arboreal lizards because their habitat would be off-limits for longer periods of time. In fact, for *Cordylidae*, the situation could be even worse. According to the model, viviparious lizards are twice as likely to go extinct as oviparious lizards, as a result of rising air temperatures (probably due to the effects of temperature on embryonic development), especially those in montane habitats. *Cordylidae* are prime candidates this regard, for they are viviparous and most species are distributed in montane habitats.

But is this global model effective? What does it actually predict for *Cordylidae* and for South Africa? The authors ground-truthed their model by re-surveying sites (or using data collected from the literature pertaining to recent surveys) in Europe, South America, Australia and Africa to determine whether populations the model predicted would be extinct by 2009 were actually extinct. Their predictions were convincingly accurate, with most sites surveyed matching the model projection. For example, the model predicted that lizards from the family *Gerrhosauridae* would be extinct in 23% of sites previously surveyed in Madagascar. In their review of recent literature, they found *Gerrhosauridae* no longer occur at an average of 21% of the sites, so it appears that the model works.

Fortunately, extinctions are not predicted to be high for *Cordylidae* at present, nor over the next 40 years, but the risk of extinction could be higher by the year 2080. Could this mean that South African fauna are, to some extent, buffered to the effects of increasing air temperatures? Probably not. Overall, their models suggest that Africa will be one of the worst hit areas, at least for lizards with a T_b < 35 °C. According to Branch, this is really just a 'wake-up call' for us. He says that while most models to date have used presence/absence data to predict range shifts and extinction risk, this new model has incorporated physiology, which results in a refinement that takes into account biologically significant traits (Branch WR 2010, personal communication). Even if the model is not 100% accurate, it is a foundation upon which to build. We already know that some lizards are predicted to have fragmented climatic space in South Africa[8,9] and those models could be refined by including data on not only T_b and CT_{max}, but also on ecologically relevant performance traits under different temperatures. Such information could be useful for understanding how lizard performance (e.g. sprinting ability) might decline before CT_{max} is obtained and thus allow the further refinement of models for predicting when and where lizards can no longer 'beat the heat'. ■

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