tipping-point TEMPERATURES

The science of predicting the future

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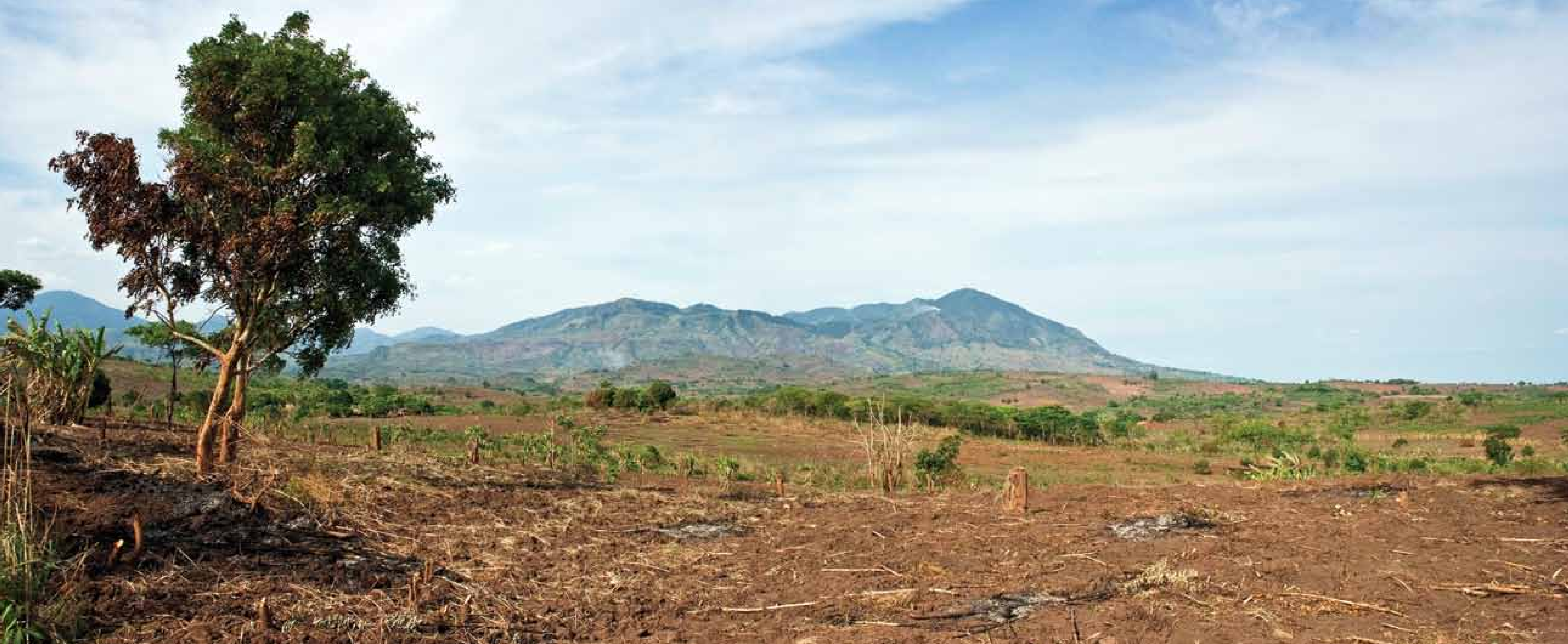

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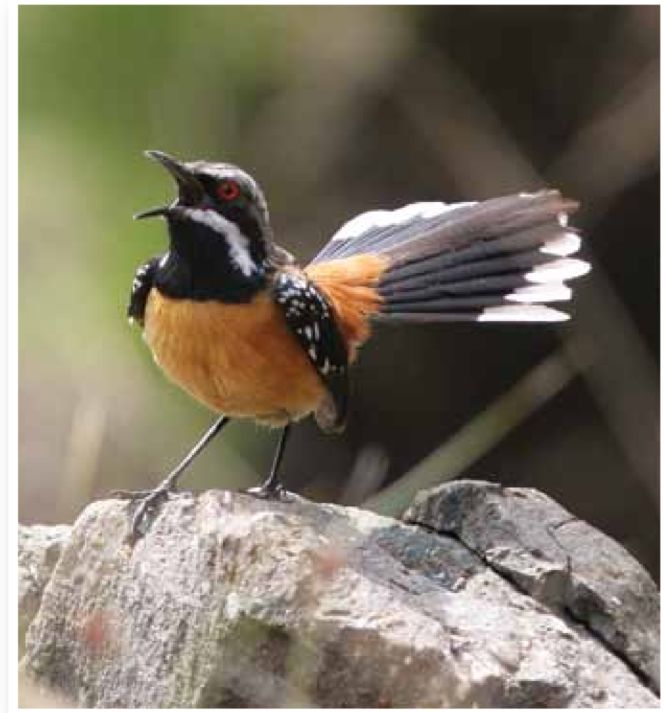

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VICTOR SOARES

CLIMATE CHANGE, on account of its pervasiveness and potential to affect virtually every ecosystem on the planet, has rapidly risen to prominence on the agendas of scientists and conservationists. Although the reality of global warming is often overshadowed by political squabbling over emissions targets and the apportionment of blame for past greenhouse gas production, a cursory examination of weather records for recent decades reveals an incontrovertible pattern of rising average temperatures and more frequent and intense heatwaves.

That the Earth's climate is changing rapidly is beyond scientifically defensible dispute. But many people remain reluctant to accept that humans are the cause, even though the overwhelming weight of scientific consensus invokes the combustion of fossil fuels as the primary driver of global warming. Debate surrounding the role of humans in causing climate change has the unfortunate effect of deflecting attention from a crucial point: in the context of biodiversity conservation, the ultimate cause of climate change – whether natural or human-driven – is moot.

The habitats in which birds must respond to climate change have been irrevocably altered by human activities, severely limiting the birds' capacities to adapt. Imagine a hypothetical period of global warming in the distant past, perhaps a million years ago. Then, forest species could have responded to rising temperatures by shifting their range polewards through vast unbroken tracts of intact forest; now, they find themselves isolated in forest fragments surrounded by plantations and cane fields. Grassland specialists such as the Blue Swallow could have tracked their habitat as it shifted to higher elevations; today, similar responses are impossible in isolated pockets of grasslands surrounded by forestry and agriculture.

So it is imperative that we understand how birds will respond to the temperature increases predicted for the 21st century, because climate change will be a key factor in determining whether conservation efforts succeed or fail. But how exactly do ornithologists predict the future? This article aims to unpack the science behind an increasingly important aspect of ornithological research and explain some of the approaches used.

TOP-DOWN...

Imagine the distribution of a bird species not as a geographic space, but as a range of climatic conditions. A widespread species will likely occupy a broad range of conditions (or 'climate envelope', in the jargon of the field), whereas for localised, habitat-specific species, like the Drakensberg Rockjumper or Blue Swallow, the respective climate envelopes are much narrower. As global temperatures increase, the position of a given climate envelope in space will shift towards cooler areas, which generally (but not always) means towards the poles and/or higher elevations.

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That, in a nutshell, is the principle behind climate envelope modelling, one of the most widely-used approaches for predicting how birds will respond to climate change. The method involves plotting a species' distribution, translating that into the range of temperatures, rainfall and other climate variables it currently encompasses, and then predicting where the corresponding climate envelope will be located under the warmer conditions of the future. Climate envelope models can also shed light on birds' responses to past events; in the wake of the devastating 2003 European heatwave, for instance, an analysis of population trends for birds in France revealed that species with narrow temperature envelopes were significantly harder hit than species with wider thermal ranges. This kind of analysis is vital for understanding how species will vary in their resilience to hotter future conditions.

Climate envelope modelling suggests that there may be serious trouble ahead for many African birds. An analysis conducted in 2004 by researchers from the Percy FitzPatrick Institute and the South African National Biodiversity Institute (SANBI) indicates that, by 2050, some local fynbos-, mountain- and Karoo-associated species, including Mountain Wheatear, Orange-breasted Sunbird and Cape Sugarbird, will lose substantial fractions of their ranges. The Drakensberg Rockjumper was identified as being particularly vulnerable; this mountain endemic is predicted to lose almost 70 per cent of its range as its already-narrow climate envelope contracts into the very coolest reaches of the Drakensberg and Maluti ranges. >

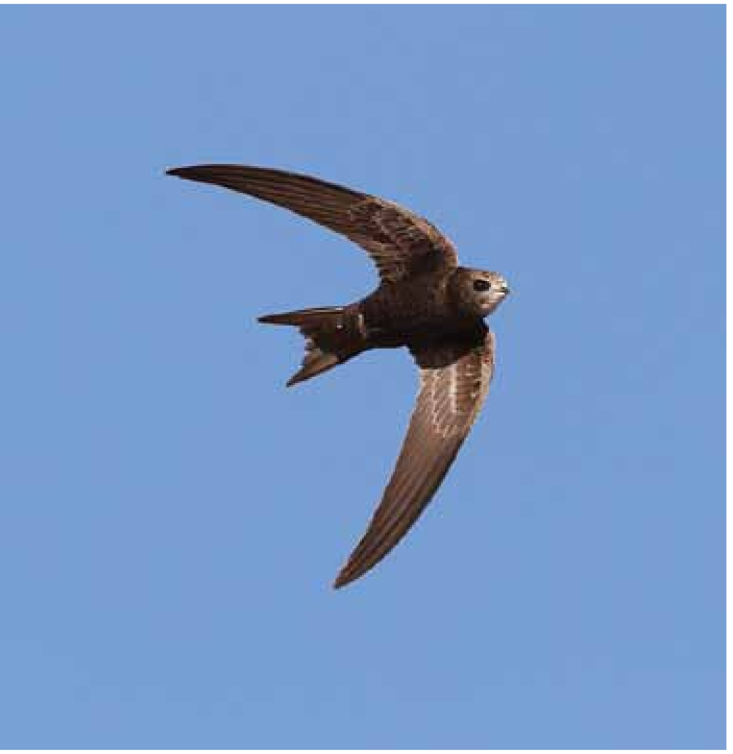
above *The Drakensberg Rockjumper is expected to lose around 70 per cent of its range under warmer future conditions.*

above, left *The destruction and fragmentation of natural habitats by humans limits the capacity of birds to adapt to climate change.*

opposite *Fynbos specialists like this Orange-breasted Sunbird are expected to be particularly hard hit by climate change.*

previous spread *Flying into an uncertain future. Cape Sugarbirds will find their habitat dwindling rapidly in the face of rising global temperatures.*

Climate envelope models remain one of the most widely-used methods for predicting species' future distributions. But increasingly they are drawing criticism, with detractors quick to point out that such models are essentially devoid of biology. Climate envelope models rely entirely on climatic variables such as temperature and rainfall, and do not in any way incorporate the ecology of the species concerned. They tacitly assume that a species is incapable of persisting outside the climate envelope it currently occupies, an assumption viewed with growing scepticism by many physiologists and ecologists.



PETER RYAN

above *The Common Swift's recent arrival in the Cape Peninsula provides a convincing example of a range expansion driven by global warming.*

opposite *A Southern Pied Babbler pants in the Kalahari heat. Panting and other heat dissipation behaviours lead to significant decreases in foraging efficiency in this species.*

There are certainly examples of species' range shifts that are consistent with the predictions of climate change models. The Common Swift, for instance, has expanded its southern African distribution approximately 1 000 kilometres southwards in the past four decades, from central Namibia in the early 1970s to the Cape Peninsula today. The most likely explanation for this species' southward expansion is that rising average temperatures have increased the availability of aerial insects for foraging swifts. But for many other species whose ranges have changed significantly in recent decades, the link to climate change is either tenuous or entirely absent.

In a series of studies examining the drivers of recent range shifts in southern African birds, the late Phil Hockey and his co-authors identified numerous instances of range changes caused by factors other than climate change. For instance, of 18 species that have colonised the Cape Peninsula since the 1940s, the Common Swift was the only one for which climate change was the most plausible explanation. For other recent arrivals in the Cape, including African Goshawk, Glossy Ibis and Amethyst Sunbird, although the southward expansion of their range might at first glance appear consistent with the core prediction of climate envelope models that most species' ranges should shift poleward, the observed range changes are in fact much more readily explained by human activities such as forestry and the creation of artificial water bodies.

… OR BOTTOM-UP?

Climate envelope models do not directly incorporate species' biology, and this has left many ornithologists doubtful as to whether these models can accurately predict birds' responses to climate change. An alternative approach, which has been steadily gaining momentum, is based on in-depth understanding of species' physiology, behaviour and reproduction. This 'bottom-up' approach directly links species' performance to environmental variables using actual data, which brings a level of biological reality that is often absent from climate envelope studies.

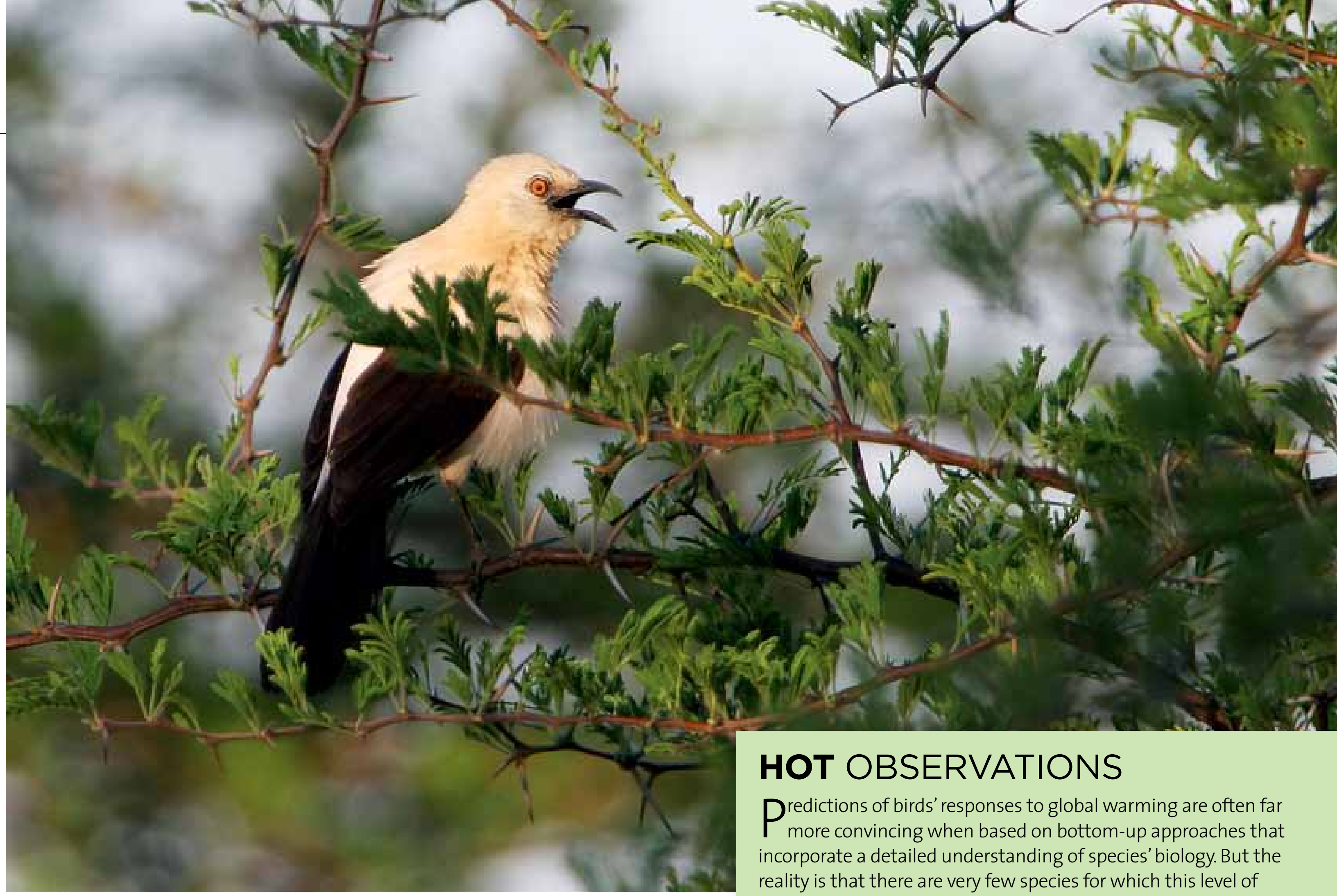
A good example of this approach has emanated from work on Southern Pied Babblers by members of the Hot Birds team, a group of researchers spread between the Fitztitute, the University of Pretoria and several overseas institutions. In 2010 Kate du Plessis, then an MSc student at the Fitztitute, examined relationships between temperature, behaviour and body condition in wild babblers in the southern Kalahari.

The babblers had previously been habituated to the presence of researchers, enabling Kate to make detailed observations of their behaviour and foraging success. She was even able to weigh the birds twice a day, by enticing each individual to hop onto a digital scale, using a scrap of hard-boiled egg as a lure.

Behaviours such as panting and wing-spreading help birds to offload heat, and are important for avoiding heat stress. Kate found that the babblers spent markedly more time engaged in these behaviours on days when the maximum temperature was above 35 °C. On these days, the babblers continued foraging while panting and wing-spreading, but the rate at which they acquired food dropped precipitously. Detailed records of individual birds' foraging success revealed that foraging efficiency (measured as grams of food obtained per minute) decreased by 75 per cent when they were simultaneously engaged in these behaviours.

But the crux of the study dealt with the effects of high temperatures in the condition of the babblers. The dramatically reduced foraging efficiency on hot days when the birds spent much of their time panting and wing-spreading resulted in a net loss of body mass, because food gained through foraging during the day was often insufficient to balance the mass loss that occurred overnight. The tipping point was at approximately 36 °C: on days when air temperature reached or exceeded this, babblers on average lost condition, whereas on cooler days they usually maintained or gained mass.

So 36 °C seems to represent a critical juncture for Southern Pied Babblers. As the frequency of days on which the temperature crosses this threshold increases, so too does the likelihood of the



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babblers experiencing sustained loss of condition, with serious negative consequences for their reproductive success. This study thus provides a clear example of how rising temperatures and more frequent hot days can negatively affect a population, and how in-depth research on avian behaviour and ecology can generate credible, biologically realistic predictions of how species should respond to climate change.

It turns out, however, that the babblers are not the only Kalahari species for which there exists an important tipping-point temperature in the mid-30s. Fitztitute postdoctoral fellow Susie Cunningham recently conducted a detailed study of the breeding biology of Common Fiscals in Tswalu Kalahari Reserve, and she found that maximum temperatures above 35 °C led to significantly delayed fledging in this species. The more frequent these very hot days, the longer the chicks remain in the nest. This link between very hot weather and delayed fledging is problematic because of nest predation: the longer a young fiscal is in the nest, the greater the likelihood that it falls victim to a predator. So for both the babblers and the fiscals an increase in the frequency of very hot days will have important negative population consequences.

Whether based on top-down or bottom-up approaches, accurate predictions of the impacts of climate change are critical for current and future conservation efforts in the face of Earth's fast-changing climate. The science of predicting these impacts on birds and other organisms is still in its infancy, and the next few decades will doubtless see important new developments in this field. One also hopes that such research will provide stimulus to efforts aimed at slowing global warming by decreasing man's unsustainable reliance on fossil fuels. ◆

HOT OBSERVATIONS

Predictions of birds' responses to global warming are often far more convincing when based on bottom-up approaches that incorporate a detailed understanding of species' biology. But the reality is that there are very few species for which this level of detailed information is available, and collecting such data is usually both time-consuming and expensive. One key question that has driven much of the research by the Hot Birds team is whether species' vulnerabilities to heat stress can be easily and rapidly assessed through behavioural observations.

Over the past few years, we have amassed more than 14 000 observations of the behaviour of Kalahari Desert birds during hot weather. It turns out that there are consistent differences between species in the temperatures at which they start showing heat dissipation behaviours such as panting and wing-drooping. These differences may, we think, hold the key to the rapid identification – using little more than a thermometer and pair of binoculars – of the species most vulnerable to future temperature increases.

In mid-2013 the Hot Birds team received a research grant from the US National Science Foundation to investigate whether these differences in behaviour do indeed reflect variation among species in their susceptibility to heat stress and dehydration during extremely hot weather.

Reference: *Du Plessis, K.L. et al. 2012. 'The costs of keeping cool in a warming world: implications of high temperatures for foraging, thermoregulation and body condition of an arid-zone bird.'* Global Change Biology *18: 3063–70.*