Sprint speed capacity of two alpine skink species, *Eulamprus kosciuskoi* and *Pseudemoia entrecasteauxii*

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Abstract

As global average temperatures continue to rise as a result of climate change, it is increasingly important to understand how some of the most vulnerable environments may be affected. The alpine environment and specialised biota of the Kosciuszko National Park are strongly influenced by abiotic factors such as temperature. Lizard performance in particular is closely related to temperature change. This study looks at the sprint speed capacity of two alpine skink species, *Eulamprus kosciuskoi* and *Pseudemoia entrecasteauxii,* as an indicator of fitness. Lizards were collected from two sites at Rainbow Lake and Charlotte Creek. These were raced over a 1 m distance and their sprint speeds were recorded at 25 cm intervals. Trials were conducted at room and elevated temperatures, and sprint times were compared between trials, species and sex and, for females, between gravid and non-gravid individuals. It was found that fitness, as measured through sprint speed, was greater at an elevated temperature for both species, and that *E. kosciuskoi* were significantly faster than *P. entrecasteauxii.* No significant differences were found between sexes or gravid and non-gravid individuals. It is possible that the lizard species studied would benefit from increased sprint performance linked to increased average temperatures; however, if temperatures rise above the skinks' physiological optima, it may have an extremely detrimental effect on all aspects of the lizards' biology.

Introduction

In the past hundred years, global average temperature has risen by 0.6 °C and is predicted to rise an additional 0.7°C by the year 2050 (Root et al. 2003; Pickering et al. 2004). This temperature change is already altering sensitive ecosystems and affecting the organisms within them, with a meta-analysis giving an average range shift of 6.1 km towards the poles and a 6.1 m shift upwards in altitude per decade (Pickering et al. 2004; Wyborn 2009). The commencement of seasonal spring events has been shown to be occurring on average 5.1 days earlier per decade in some species (Root et al. 2003). With significant changes already shown to be occurring (Root et al. 2003; Pickering et al. 2004; Wyborn 2009), it is increasingly important to understand the potential effects of climate change on the environments most severely at risk and their biota.

The alpine environment of the Kosciuszko National Park (KNP) is especially vulnerable to climate change, and its effects are already discernable in the changing snow and fire patterns (Pickering et al. 2004; Wyborn 2009). The functionality and differentiation of alpine environments is largely governed by temperature and other abiotic factors such as precipitation, especially that of snow (Pickering et al. 2004). Along with the forecasted rise in temperature, a dramatic reduction in snow cover and duration of snow coverage is expected. These changed conditions will have a considerable impact on the density and diversity of the region's specialised biota, as rising temperatures and reduction of snow coverage compress already narrow thermal environments and lowland species shift upward in altitude (Pickering et al. 2004). To best understand and predict changes to KNP's flora and fauna, it is essential to investigate the tolerances species might have to changed conditions and rising temperatures.

Understanding the thermal tolerances of KNP fauna will give an indication of the resilience of the species and help predict possible changes in distribution as temperatures increase. Reptiles, as ectotherms, are particularly sensitive to temperature and their fitness would be directly affected by changes to the annual means. Sprint speed capacity is a valuable indicator of species fitness. Faster individuals are more likely to avoid predation by fleeing and have an advantage as predators themselves. Greater speed has also been linked to social dominance and mating success (Beal et al. 2014). Maximal sprint performance has been linked to

optimal temperature, and it has been shown in a number of lizard species that 'hotter is better' (i.e. they perform better at higher temperatures) (Zamora-Camacho et al. 2015). This has been shown to be equally true of warm- and cold-adapted species (Van Damme and Vanhooydonck 2001). However, other factors also have an influence on sprint capacity. The size and gravid status may all influence the lizard's speed and response to increased temperatures. Smaller and gravid lizards expected to be slower (Beal et al. 2014), though gravid individuals may have a higher sprint capacity at elevated temperatures due to having a higher thermal preference that benefits embryogenesis (Schwarzkopf and Shine 1991; Clusella-Trullas and Chown 2014).

We investigated the sprint capacities of two skink species found within KNP, *Eulamprus kosciuskoi* and *Pseudemoia entrecasteauxii*, at current and elevated temperature conditions, to see how rising temperatures within the park would affect the species. We predicted that both species would display greater sprint capacity with the increased temperature, but the smaller species, *P. entrecasteauxii*, would have a lower peak performance and that the gravid females of both would be significantly slower.

Methods

Study site

Kosciuszko National Park covers 690,411 hectares of Australian wilderness, making it one of the largest reserves in the country (Wyborn 2009). The park encompasses a large variety of biomes with distinct floral and faunal compositions (Pickering et al. 2004). The skink collection sites were Rainbow Lake, an artificially created lake off the Kosciuszko Road, and Charlotte Creek, which passes through the Charlotte Pass Snow Resort at 1,765 m.

Collection and husbandry

Twelve *P. entrecasteauxii* skinks were collected at the Rainbow Lake site using a baiting technique. Fishing rods were baited using mealworms tied to dental floss and were used to lure the lizards into the open and distract them while they were captured. Lizards were place in individually numbered fabric bags. Sixteen *kosciuskoi* skinks were collected using

a noosing technique. Dental floss nooses were attached to the ends of fishing rods. These were slipped over the heads of the lizard and pulled tight, allowing for the lizard's capture. Captured lizards were placed in individually numbered fabric bags. Lizards were housed in individual, numbered plastic containers, containing a woodchip substrate, cardboard tube and a plastic drink lid containing water.

Measurements

The lizards were measured and their sex determined. Snout-to-vent and tail lengths were taken by stretching the lizard out against a clear ruler, and head length and width were measured with calipers. Weight was measured by placing lizards in a beaker on an electronic scale.

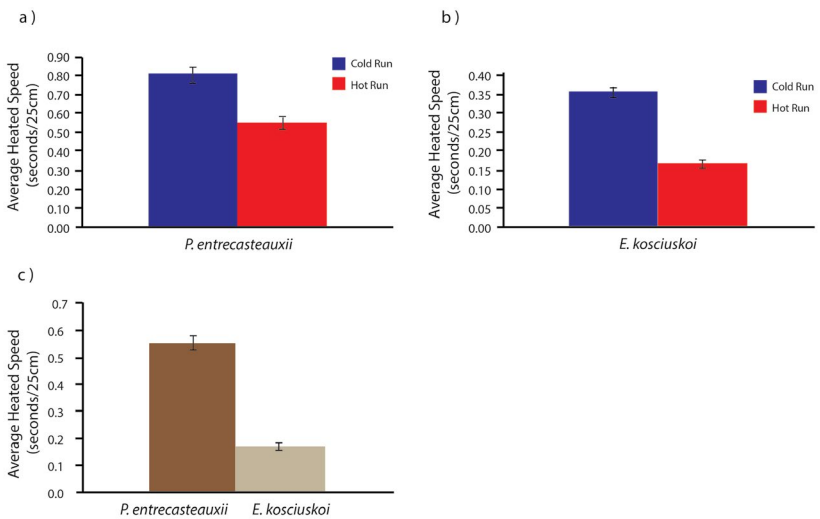

Figure 1: a) Comparison of *P. entrecasteauxii* speed between room temperature and heated runs, lizards were significantly faster after heating (P=0.002), b) Comparison of *E. kosciuskoi* speed between room temperature and heated runs, lizards were significantly faster after heating (P<0.001), c) Comparison of speed between species of lizard, *E. kosciuskoi* significantly faster than *P. entrecasteauxii* (P<0.001).

Source: Authors' data.

Lizard sprint speed was measured using a photocell-type racetrack. Lizards were released before the starting line and coaxed in the desired direction by a person running a broad paintbrush behind the lizard at a consistent speed. The racetrack terminated at the end of the table, where the lizard

would be caught in a bucket. Lizard speed was recorded every 25 cm over the 1 m track and the fastest time was recorded. Each lizard was raced three times consecutively and two trials were conducted. One trial was conducted at room temperature and the second after the lizards were heated in paper bags for 1 hour at 32°C in an oven.

All lizards were released at the original sites of collection at the conclusion of the final trial.

Results

It was found that sprint performance in both *P. entrecasteauxii* and *E. kosciuskoi* was significantly improved after heating (P=0.002 and P<0.001 respectively), with *E. kosciuskoi* showing a greater increase in speed. *E. kosciuskoi* was shown to be significantly faster than *P. entrecasteauxii* (P<0.001). Differences in the average speeds of the female, male and gravid individuals were observed for both species, though were not found to be statistically significant (P=0.408 for *P. entrecasteauxii* and P=0.285 for *E. kosciuskoi*).

Discussion

An increase in the skink's body temperature resulted in an increase of average sprint capacity for both species. The overall average speed was greater for *E. kosciuskoi* and no significant difference was found between sexes or gravid and non-gravid individuals.

Global temperatures have risen 0.6°C in the last century and are set to rise an additional 0.7 °C over the next 50 years. This will have a significant effect on the alpine environment of the KNP. As temperatures increase, the thermal tolerances of the region's biota become increasingly important (Root et al. 2003; Pickering et al. 2004). The fitness of reptile species is closely correlated with temperature, and sprint speed capacity may be used as an indicator for lizard fitness (Beal et al. 2014). For the two lizard species studied fitness as measured through sprint speed was shown to increase at an elevated temperature.

For both species, sprint speed increased significantly after the lizards were heated, with *E. kosciuskoi* run times reduced by more than half (Figures 1a and 1b). This is consistent with the idea that 'hotter is better', as shown in previous studies on other lizard species (Zamora-Camacho et al. 2015). *E. kosciuskoi* lizards were significantly faster than *P. entrecasteauxii* lizards (Figure 1c). This is most likely due to their smaller size (Beal et al. 2014). Between the sprint capacities of the male, female and gravid individuals, no significant difference was discerned for either species, which is also consistent with the Beal study (Figures 2a and 2b), though it suggests the higher thermal preference of gravid females (Schwarzkopf and Shine 1991) does not result in a significant increase in speed.

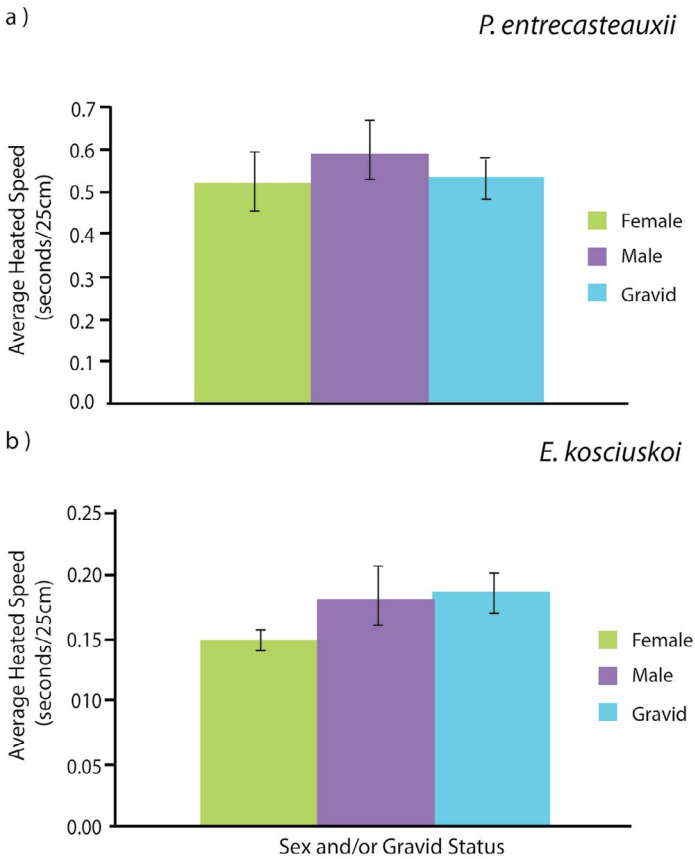

Figure 2: Comparison of heated run speed between male, female and gravid individuals of a) *P. entrecasteauxii* and b) *E. kosciuskoi*. No significant differences were observed between the groups.

Source: Authors' data.

Though the difference in sprint speed between room temperature and heated runs and between species were statistically significant, a large amount of variation existed between lizards within a trial and even within the run times of individual skinks. This may be due to a number of factors including inconsistency in the pace of prompting with the paintbrush and fatigue in the lizards that escaped from the racetrack, ran back toward the starting line or stopped and were required to run the track more than three times to obtain viable readings. An enclosed track and automated prompt may help reduce these sources of error. The ratio of sex and gravid status was also highly skewed towards females and gravid females in particular, as females tend to bask more, making them more likely to have been collected. This may have affected the comparisons in Figures 2a and 2b. It is also possible that the collected skinks were slower individuals, more susceptible to capture. A larger sample size, with a more even distribution of sex and gravid status would likely provide a more representative sample.

With fitness increasing at an increased temperature, it is possible that both lizard species will benefit from rising temperatures in the KNP region regardless of sex or gravid status. It may allow them to more easily escape predators, hunt more effectively and extend their ranges to higher altitudes as they warm. However, trials were run at only two temperatures and further trials at various temperatures would need to be conducted to determine the lizard species' optimal temperature and determine the effects of above optimal temperatures on lizard fitness. If temperatures continue to increase above the thermal preferences and tolerances of the skink species, it is likely that their physiology will be negatively impacted.

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