Temperature along an elevation gradient determines Galapagos tortoise sex ratios; a summary.

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This article is a summary of an original paper (Deem, S. L., Rivera, S., Nieto-Claudin, A., Emmel, E., Cabrera, F., & Blake, S. (2023). Temperature along an elevation gradient determines Galapagos tortoise sex ratios. *Ecology and Evolution* 13: e10008. https://doi.org/10.1002/ece3.10008)

Introduction

Chelonia – turtles and tortoises – are the most imperiled group of vertebrates with over 60% of the 356 known species threatened with extinction. Galapagos tortoises are no exception. Of the 15 known species of Galapagos tortoises, three species (20%) are vulnerable, three species (20%) are endangered, six species (40%) are critically endangered, and three species (20%) were driven to extinction in modern times. The 12 extant Galapagos tortoises continue to face multiple challenges that threaten their long-term survival. These threats include invasive plants and animals, pathogens, habitat degradation and climate change.

In the study, *Temperature along an elevation gradient determines Galapagos tortoise sex ratios* (Deem et al. 2023), we explored whether the elevation at which a female tortoise lays her eggs impacts the sex ratio of her offspring, and how this may be influenced by climate change in the coming decades. We performed this study knowing that climate change threatens endemic island ectothermic reptiles that display small population sizes, and temperature-dependent sex determination (TSD). Galapagos tortoises have all three of these characteristics – island ectotherms, small population sizes, and TSD.

Previous studies support Galapagos tortoises as having type A TSD with warmer incubation temperatures producing females (Sancho et al. 2017). Therefore we wondered if, in a warming world, climate change will impact sex ratios of free-living tortoises in the Islands.

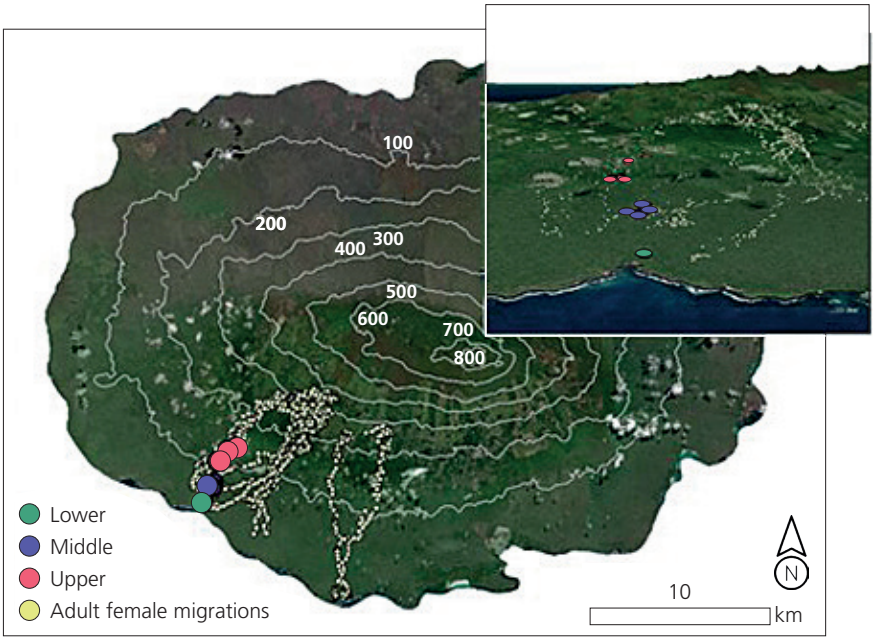

Fig. 1. Locations of three Galapagos tortoise nesting zones in the El Chato region of Santa Cruz Island, Galapagos. Seasonal migration data of adult female tortoises are from Yackulic et al. (2017). Map insert exaggerates elevation three-fold. Reproduced by permission from Deem et al. (2023).

Method

We performed the study on Santa Cruz Island at a site where the Galapagos Tortoise Movement Ecology Programme (Blake et al. 2021) has been studying the movement and health of *Chelonoidis porteri* over the past 13 years (Fig. 1). At this site there are three distinct nesting zones along an elevation gradient from sea level to 165 metres. Therefore, we could explore whether environmental differences influence nest temperatures and if so, how these differences may impact the sex ratio of hatchlings.

A first step in our study was to record nest temperatures along the elevation gradient. When nests were found, nest cavities were carefully opened to place a miniature temperature sensor among the eggs, then the nests were closed to continue their natural incubation. The next step was to determine the sex of juvenile tortoises we encountered, either opportunistically during searches or via radio tracking of previously tagged individuals. To determine the sex of these individuals, we performed coelioscopic sexing of anesthetized tortoises using a rigid endoscope (Emmel et al. 2020).

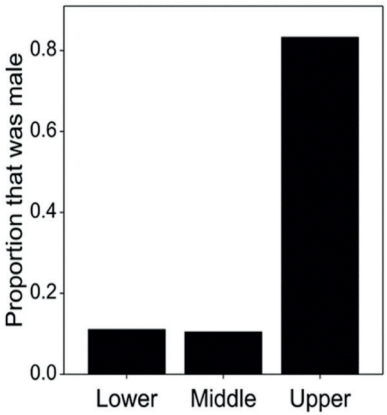

Fig. 2. The majority (80%) of juvenile Western Santa Cruz Giant Tortoises in the upper nesting zone were males, whereas in the lower and middle nesting zones, males made up only 11% and 10% of juveniles, respectively. Image: Deem et al. (2023).

Results

Our findings demonstrate that during the critical period of sex determination, nest temperatures were much warmer in low and middle elevation nests, but cooler in the high elevation nests. In the warmer lower and middle elevation nesting zones, approximately 90% of juvenile tortoises were females. In contrast, in the cooler higher elevation nesting zone, 80% of juvenile tortoises were males. Small increases in elevation (of approximately 50–100 metres) resulted in cooler nest temperatures (by about 1.6°C) and a dramatic flip from strongly female-biased sex ratios at lower elevations to a strongly male-biased sex ratio at the highest elevation (Fig. 2).

Discussion

Taking these findings of more males in the higher, cooler elevation zone, we discuss what impacts climate change may have on sex ratios of tortoises. Based on climate change predictions for the Galapagos, it is likely that an increase in female hatchlings will occur even at the highest nesting zone (Fig. 3). In the short term, this may be beneficial since female recruitment and particularly survival is often the limiting factor in tortoise reproduction. However, in the longer term it may erode genetic diversity.

On a warming planet, these observations may be generally applicable to other species that display TSD. However, we must remember that incubation temperature affects different species in myriad different ways. Even in Galapagos, there may be differences in climate change impacts on the different species of tortoises. That said, these preliminary data allow us to consider the impacts that climate change may have on future sex ratios of these iconic island species.

To read the full scientific article, please visit *Temperature along an elevation gradient determines Galapagos tortoise sex ratios*. Deem et al. (2023).

Fig. 3. Climate change and the nesting decisions made by females will strongly influence future sex ratios and populations of Galapagos giant tortoise. Photos by Stephen Blake and reproduced by permission from Deem et al. (2023).

References

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