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Thermal habitat of giant panda has shrunk by climate warming over the past half century

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ABSTRACT

Climate warming is increasing the risks of extinction for many species. Giant panda is one of the most vulnerable mammals to climate warming due to its small population size and specialized diet of bamboo. Many studies have quantified projected habitat loss based on climate-change scenarios, but few have employed empirical data to investigate how the thermal habitat of giant panda has changed. In this study, we investigated the frequency, duration, and intensity of potential heat stress (PHS) occurrence that could surpass the biological threshold of giant panda by analyzing daily temperatures throughout the distribution range of giant panda from 1960 to 2010 and giant panda population survey data. We found an increase in the frequency of PHS25 (PHS above threshold of 25 °C) occurrence at a rate of 1.1–5.5 days/decade. The start date of PHS25 occurrence advanced at a rate of − 1.2 to − 4.6 days/decade, while the end date of PHS25 occurrence was delayed at a rate of 0.8–3.0 days/decade. The giant panda habitat is being exposed to an increased PHS occurrence. The area within reserves and densely populated giant panda habitat exposed to PHS occurrence expanded by 32–317% and 38–218%, respectively from the 1960s to the 2000s. Furthermore, PHS occurrence is intensifying; the annual accumulated degree-days of PHS25 and PHS30 occurrence (PHS above threshold of 30 °C) within the reserves increased by 39% and 140%, respectively. These results confirm that the potential threats to giant panda from climate warming are intensifying. It is urgent to expand the extent and range of giant panda habitat to allow giant pandas to move across landscapes in the face of ongoing climate warming.

1. Introduction

The fifth assessment report of the Intergovernmental Panel on Climate Change demonstrated an increase in global land and ocean surface temperature of approximately 0.89 °C (0.69–1.08 °C) during the last century, and an increase of 1.0–4.0 °C is projected by the end of the 21st century (Stocker et al., 2013). Climate warming is affecting organisms by shifting their phenology and ranges, and causing habitat fragmentation and loss (Chen et al., 2011; Miller-Rushing and Primack, 2008; Parmesan and Yohe, 2003). Species can cope with ambient temperature increases by moving to more favorable locations, shifting the timing of life-history events, or adjusting their posture and physiological functions (Bellard et al., 2012; Porter and Kearney, 2009).

However, when ambient temperature increases beyond a species' suitable thermal range, there is a potential for species to become heat stressed, and when populations of a species suffer from prolonged exposure to potential heat stress (PHS), they face increased risk of extinction (Angilletta et al., 2010; Huey et al., 2012; McNab and Morrison, 1963). Multi-taxon reviews suggest that 20–30% of global plant and animal species could be at an increased risk of extinction due to climate warming (Parry et al., 2007), and continued warming will drive 16% species to extinction by 2100 (Urban, 2015). Tolerance to heat is largely conserved across lineages, and hard physiological boundaries exist that constrain evolution of tolerances of terrestrial

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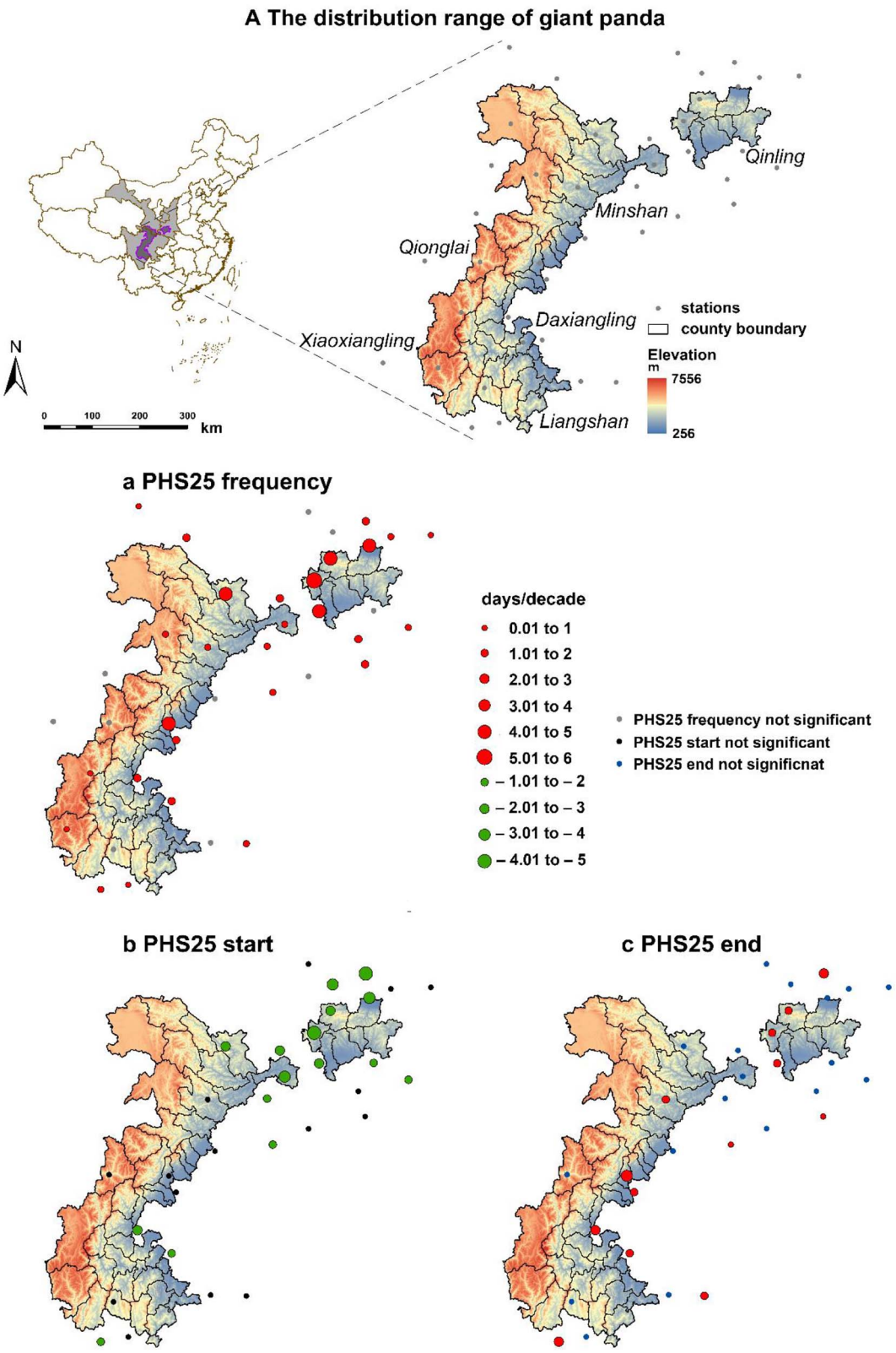

Fig. 1. Maps of **A** study area which spans six mountain ranges, and the rate of change in **a** the frequency of PHS25 occurrence; **b** the start date of PHS25 occurrence; and **c** the end date of PHS25 occurrence. Light grey circles show stations that had non-significant trends in the frequency of PHS25 occurrence, dark circles show stations that had non-significant trends in the start date of PHS25 occurrence, blue circles show stations that had non-significant trends in the end date of PHS25 occurrence; green circles show stations that had significant negative trends, and red circles show stations that had significant positive trends over time. Size of circles shows the magnitude of change rate. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)