



HOKKAIDO UNIVERSITY

Title	The role of microclimate in maintaining species distribution under climate change : a case study of the northern pika [an abstract of dissertation and a summary of dissertation review]
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Degree Grantor	北海道大学
Degree Name	博士(環境科学)
Dissertation Number	甲第16073号
Issue Date	2024-09-25
Doc URL	https://hdl.handle.net/2115/93424
Rights(URL)	https://creativecommons.org/licenses/by/4.0/
Type	doctoral thesis
File Information	SAKIYAMA_Tomoki_review.pdf, 審査の要旨



学 位 論 文 審 査 の 要 旨

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学 位 論 文 題 名

The role of microclimate in maintaining species distribution under climate change
: a case study of the northern pika

(気候変動下の生物分布における微気候の重要性：キタナキウサギにおける検証)

Anthropogenic climate change poses a global threat to biodiversity. One of its widespread impacts on terrestrial ecosystems is the change in species distributions as species shift their distributions towards cooler environments under a warming climate. This reshuffling of biodiversity can bring negative consequences for ecosystem functions and services. It is therefore imperative to understand the mechanisms shaping species distributions and predict how such distributions may change under climate warming.

Despite existing evidence for an overall general trend of species shifts towards higher latitudes and elevations, many species have not shifted their distributions significantly or are doing so at slower rates than expected based on climate warming. One hypothesis gaining increasing momentum is that complex topography can facilitate species persistence by decoupling local climatic conditions (microclimates) from the regional climate. However, few studies have yet assessed the effectiveness of microclimates in maintaining species distribution particularly regarding spatial scale and relative importance with other environmental factors. Similarly, few studies have properly validated the accuracy of predictions of species distributions that incorporate the effect of microclimates. This dissertation contributes to address these knowledge gaps by assessing the role of microclimates in maintaining the distribution of the northern pika (*Ochotona hyperborea*), a climate-sensitive small lagomorph in Hokkaido, Japan. In particular, the thesis made the following significant novel contributions.

Chapter 2 tested a playback aural detection method for surveyance of pika occupancy (presence/absence) using prerecorded acoustic cues to trigger response vocalizations from the animal. The method was found to be much more time-effective and equally reliable to the traditional passive aural method, where natural vocalizations (without stimulus) are recorded (published in the Journal of Mammalogy doi 10.1093/jmammal/gyad066).

Chapter 3 used habitat resurveys to provide the first evidence of an ongoing upward

elevational shift in the distribution of the northern pika in Hokkaido as the species is becoming extirpated from low- to mid-elevation sites where it was historically present. The analysis also found a positive correlation between species persistence and habitat size plausibly linked to the larger environmental heterogeneity existing in larger habitats (i.e., more extreme variations in local thermal conditions).

Chapter 4 explored the importance of thermal conditions for site occupancy. Although rock interstice effectively buffered ambient thermal conditions (having temperatures up to 4°C below ambient temperatures), interstice temperatures were found to have no significant effect neither for the whole distribution or at the trailing (low elevation) edge of the distribution. Conversely, factors such as local ambient temperature and microhabitat availability were found to influence occupancy for the whole distribution, whereas presence of human land use was the most important factor at the range edge evidencing the importance of the environmental context in which the microclimate exists for driving species persistence (published in the *Journal of Biogeography* doi 10.1111/jbi.14815).

Chapters 5 and 6 incorporated findings from the other chapters to develop and test the performance of a fine-scale distribution model. By accounting for the effect of rock interstice temperatures the model predicted distinctively higher habitat suitability for low- to mid-elevation areas and had higher prediction accuracy (lower omission error) relative to models that did not include the microclimate effect. Models were then used for projecting the future distribution of the species under future climate change scenarios showing how rock interstice microclimate may provide suitable habitats for the species in areas where the regional and local climate becomes otherwise unsuitable.

Overall, this thesis represents a significant contribution to the broad field of climate change ecology and conservation by (i) providing novel evidence of the potential of complex topographies to facilitate species persistence at the trailing edge of their distribution under climate warming contextual to other existing environmental factors, and (ii) demonstrating how the incorporation of microclimates into species distribution models can provide more accurate predictions of range shifts under climate change. Further, it documents the first empirical evidence on an ongoing upward range shift of the northern pika in Hokkaido while providing a much needed update of its current distribution status and information on the environmental factors driving such distribution dynamics that will undoubtedly contribute to improve the conservation and management of the species.

All examination committee members agreed on the high quality and novel contribution of this thesis and praised the work conducted by the candidate exemplified by his outstanding academic record generated during his Ph. D. including journal publications, presentations at national and international conferences, and acquisition of competitive research funds. Considering this and the fulfilment of the required credits for his Ph. D. course, the committee unanimously concluded that Mr. Tomoki Sakiyama is eligible for the degree of Doctor of Philosophy in Environmental Science.