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Threatened grassland butterflies as indicators of microclimatic niches along an elevational gradient – Implications for conservation in times of climate change

Gregor Stuhldreher[a,*], Thomas Fartmann[a,b]

[a] Department of Biodiversity and Landscape Ecology, University of Osnabrück, Barbarastr. 13, 49076 Osnabrück, Germany
[b] Institute of Biodiversity and Landscape Ecology (IBL), Hafenweg 31, 48155 Münster, Germany

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ABSTRACT

Among the factors that determine habitat quality for butterflies, an adequate microclimate is of crucial importance, especially for the less mobile immature stages. Due to their narrow microclimatic preferences, stenotopic butterflies are potential indicators of specific microclimatic niches. Although the outstanding importance of the microclimate is widely acknowledged, the thermal and hygric requirements of butterflies are usually inferred from habitat structure or regional climate instead of being exactly measured. Here, we present the results of year-round measurements of temperature and relative air humidity at typical oviposition microhabitats of three threatened grassland butterflies (*Erebia medusa*, *Melitaea aurelia* and *Satyrium spini*) inhabiting different zones along a climatic gradient in the Diemel Valley (Central Germany). Furthermore, we analysed how the climate in the study area has changed since the middle of the 20th century.

The interspecific differences in mean temperature and humidity at the oviposition sites roughly reflected the differences in overall distribution of the three species, but separate analyses of day- and nighttime values revealed that local habitat characteristics and radiative heating of the near-ground air layer have a strong modifying effect on the microclimate.

Since the 1950s, the climate in the Diemel valley has become significantly warmer. The magnitude of the observed increase in mean temperature was similar or even greater than the interspecific differences recorded by the microclimatic measurements. This implies that thermophilous species may expand their ranges within the Diemel Valley if climate warming continues. Species living in the relatively cool Upper Diemel Valley such as *E. medusa*, however, may incur population declines because there are few grasslands available at higher elevations or at microclimatically cooler sites such as north-facing slopes.

1. Introduction

Since the beginning of the industrial era, humankind has altered the physical environment of the Earth at an unprecedented rate (Rockstroem et al., 2009). Besides other factors such as land-use change and alterations of the nitrogen cycle, climate warming is one of the main drivers of this global change (Sala et al., 2000). Taxonomic groups with many highly specialised species exhibit particularly fast and strong responses to climatic change and, therefore, are highly suitable as model organisms for assessing the impact of global warming (Parmesan, 2003; Thomas, 2005). Butterflies are one of these indicator groups because many of them exhibit strong climatic associations (Dennis, 2010; Settele et al., 2008; Thomas, 1993). They are frequently used to study the effects of rising temperatures on their phenology (Roy and Sparks, 2000; Van Dyck et al., 2015), habitat preferences, biotic interactions (Boggs and Inouye, 2012) and their latitudinal (Devictor et al., 2012; Thomas et al., 2001a) and altitudinal (Wilson et al., 2005) distribution. There are strong differences between species regarding their response to recent climate change. Thermophilous species usually benefit from global warming and, consequently, extend their ranges polewards and to higher elevations. Taxa adapted to cooler climates, however, often suffer from deteriorating living conditions at the low-latitudinal and low-elevational boundaries of their ranges (Dieker et al., 2011; Konvicka et al., 2003; Wilson et al., 2005). Consequently, they have to move to higher latitudes or elevations. If such movements are not possible, e.g., due to habitat fragmentation or lack of suitable habitats at higher elevations, range retractions are the consequence (Hill et al., 2002; Warren et al., 2001).

* Corresponding author.
E-mail addresses: gstuhldreher@uos.de (G. Stuhldreher), t.fartmann@uos.de (T. Fartmann).

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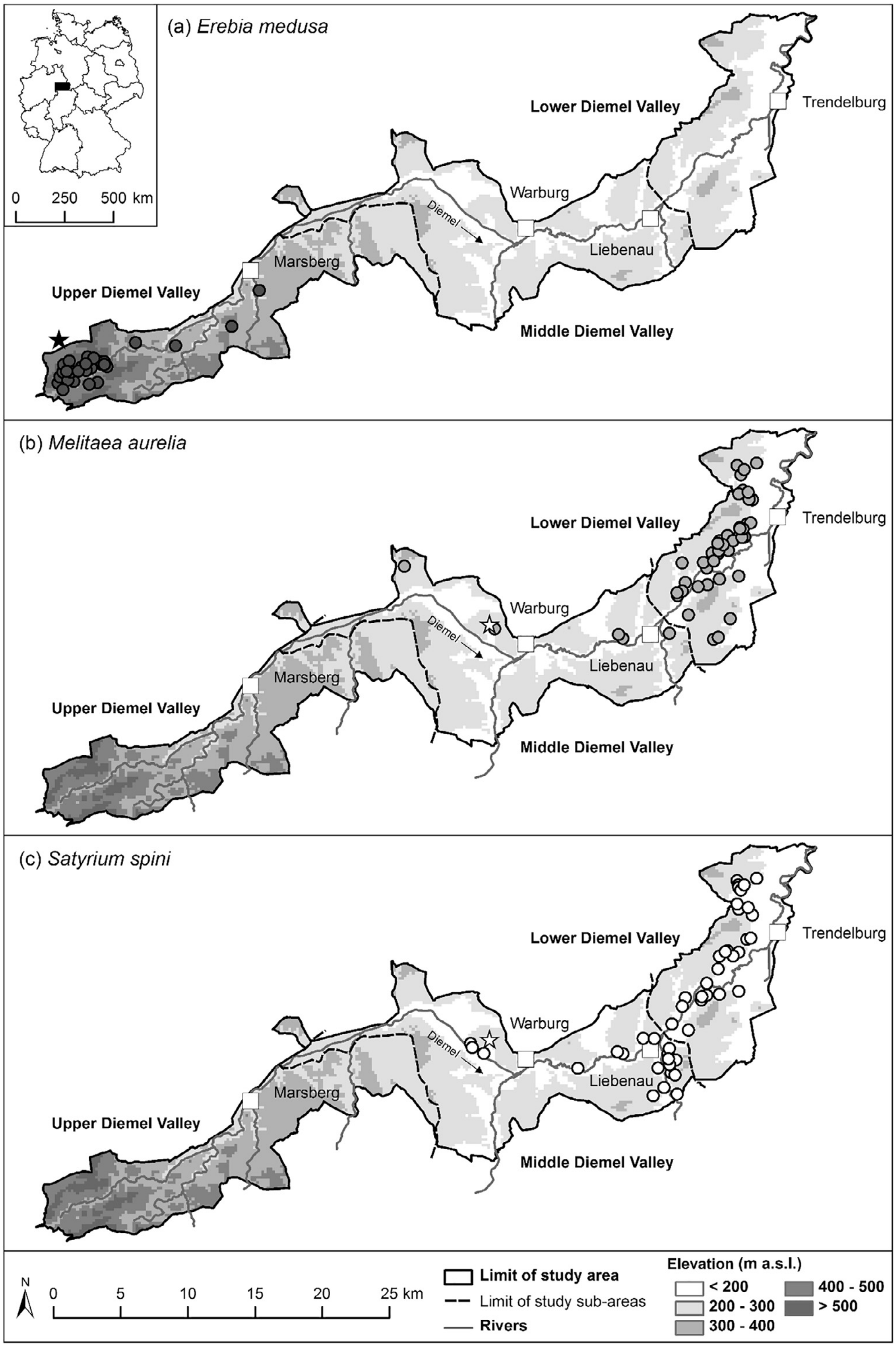

Fig. 1. Distribution of *Erebia medusa*, *Melitaea aurelia* and *Satyrium spini* in the Diemel Valley in Central Germany. Each circle corresponds to an occupied habitat patch. The surveys were carried out in 2009 for *S. spini* and in 2010 for E. *medusa* and *M. aurelia*. The black and white asterisks represent the weather stations in Brilon and Warburg, respectively, from which reference data for temperature and relative humidity were obtained.

The spatial distribution of butterfly populations is crucially determined by habitat quality within patches, whose importance typically equals or exceeds that of patch size and isolation from neighbouring populations (Anthes et al., 2003; Eichel and Fartmann, 2008; Stuhldreher and Fartmann, 2014; Thomas et al., 2001b, 2011). Habitat quality is best defined on the basis of the ecological requirements of the immature stages (eggs, larvae and pupae) because they often have more specific habitat requirements than adults (Fartmann and Hermann,