Temperature of stridulation location in an alpine cricket species, *Gomphocerus sibiricus* (Linnaeus, 1767) (Orthoptera, Acrididae)

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Abstract

The ambient temperature has a great influence on the mating activity of ectothermic animals such as orthopterans. These insects have to modulate their behaviour in order to reach optimal temperature. In most orthopterans' species, males display mating calls that are structurally influenced by the temperature. In this study, we measured both the temperature range and the mean conditions around stridulating males of *Gomphocerus sibiricus* (Linnaeus, 1767) (Orthoptera, Acrididae), an alpine cricket species. We show that there is a wide temperature range in *G. sibiricus* environment and that males significantly prefer to stridulate from location at around 28 °C. Further studies would be necessary to better understand how microhabitats and their associated temperature are important in orthopterans life.

Keywords: Microhabitats, nuptial parade, Siberian grasshopper.

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Résumé

La température ambiante est d'une grande importance pour les organismes ectothermes en influençant particulièrement certaines parties de leur cycle de vie comme la reproduction. De plus hautes températures renforcent généralement les comportements reproductifs, alors que des températures plus basses tendent à les diminuer, obligeant les ectothermes à moduler leur comportement, afin d'atteindre une température idéale. L'étude des facteurs influençant ces comportements est grandement facilitée en considérant des parades nuptiales stéréotypées comme celles des orthoptères dont les mâles produisent des signaux sonores à l'intention des femelles. Nous nous sommes intéressés à la température des sites de stridulation sélectionnés par les mâles de *Gomphocerus sibiricus* (Linnaeus, 1767) (Orthoptera, Acrididae), une espèce alpine de criquet. Nous avons utilisé deux méthodes : l'une permettant de prendre en compte la variation de température présente dans les diverses strates de végétation, formant des microhabitats aux conditions microclimatiques différentes disponibles pour *G. sibiricus* et la seconde pour caractériser les conditions moyennes dans l'environnement direct des mâles stridulants. Nos résultats montrent

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que les individus choisissent des sites où la température est d'environ 28 °C alors même qu'un très large choix de température s'offre à eux (de 12,4 à 69 °C). Des études supplémentaires pourraient être menées afin de voir si d'autres microhabitats (et leurs températures associées) sont importants dans d'autres phases du cycle de vie de *G. sibiricus* ce qui permettrait de souligner l'importance d'un habitat hétérogène pour les orthoptères.

Mots-clés : Gomphocère des alpages, Microhabitats, Sibirische Keulenschrrecke, parade nuptiale.

Introduction

Ambient temperature has a great importance for many animals and especially for ectotherms by directly affecting their metabolism rate (Hoffmann 1984) but also causes conformational transitions of proteins, phase transitions of lipids, changes in the structure of water, etc. (Alexandrov 1977). Ectothermic organisms have to modulate their behaviour (Dunham *et al.* 1989, Willmer 1991) in order to reach desired temperatures. Many aspects of their life cycle such as mating activity are dependent of the temperature, with warmer temperatures usually enhancing mating's behaviour while cooler temperatures reducing it (Edmunds 1963, Shimizu & Barth 1996, Kindle *et al.* 2006).

In orthopterans, temperature has an important influence on signals displayed by males (Souroukis *et al.* 1992, Walker & Cade 2003). The stereotyped signal is composed of repeated pulse of sound, which tends to increase with temperature (Heath & Josephson 1970, Martin *et al.* 2000, Hedrick *et al.* 2002, Walker & Cade 2003). Several studies have shown females preferences for some song variant within the normal range of variation (Wagner, 1996, Simmons *et al.* 2001). Male signalisation having a major function in the attraction of mates and females having preferences for some specific song variants, temperature may therefore importantly influence the reproductive success of males.

In natural environment, organisms have a wide choice of microhabitats with various associated temperatures (Powers & Cole 1976, Guido & Gianelle 2001, Helmut & Hoffmann 2001). The important effects of the temperature on mating displays and the reproductive success of orthopterans suggest that males should select locations with an optimal temperature to stridulate. It has been shown for example that *Gryllus integer* males select preferentially warmer singing location (Hedrick *et al.* 2002). However, in this species males are linked to a specific habitat structure since they sing from their den. Surprisingly, only few studies have documented temperatures at which some orthopteran species call (Souroukis *et al.* 1992, Ciceran *et al.* 1994), but none of these studies show a choice between different microhabitat and temperature.

In this study, we describe the optimal temperature selected by the males of *Gomphocerus sibiricus* (Linnaeus, 1767), an alpine cricket species, to stridulate in natural conditions by measuring temperature at the precise stridulation location and in the direct surrounding environments.

Material and methods

Study area

This study was conducted between the 7 and the 9 of July 2020, by sunny weather in the alpine valley of Arolla in the southwestern Swiss Alps between the altitudes of 2 000 and

2 500 m. The landscape consisted of a mosaic of alpine grasslands (mostly pastures), shrubs and forests. We concentrated our prospections outside of the forested areas, on the south exposed slopes, where *G. sibiricus* is expected in high density (Pöppl 2009). In July *G. sibiricus* finishes its larval period and males are easy to find following their stridulation.

Sampling

We used two methods in order to characterize the complete range and the mean temperature present in the environment surrounding directly the stridulating males. The specimens were identified with their distinctive dilated tibiae, according to specialized literature (Baur *et al.* 2006).

Method 1 (transect)

The first two days, we aimed to look at the complete range of temperatures available in the different microhabitats around males of *G. sibiricus*. We looked for stridulating males, marked their exact location and placed a transect going from one singing place to another, including control points (locations without singing males). One and a half to two meters were always separating the points. We measured the temperature at the points and in each of the microhabitat categories: surfaces covered by rock, bare soil, shrubs, tall herbaceous plants (> 10 cm high) and small herbaceous plants (< 10 cm high) in a 1-meter square surrounding. Temperature was measured using an infrared thermometer. In total, we placed 15 transects with 40 singing points and 37 control points.

Method 2 (grid)

The third day, we complemented our study with a second method focusing on the mean condition in the surroundings of stridulating *G. sibiricus* males. We placed one-meter squares subdivided in 25 smaller squares centered on stridulating males and took a measure of the temperature in the center of each of the sub-squares (1 presence point and 24 background points). In total, we measured the temperature around 14 singing males.

Data analysis

To detect the optimal microhabitat temperature for the *G. sibiricus* singing males, we chose to run for our two methods a Generalized Linear Mixed Model (GLMM) to take into account the possible lack of dependence inside transects or squares. The presence of a singing male was the response variable, the temperature, the explicative and the squares or transects the random factor. In addition, we tested the difference of the mean temperatures measured in each of the visible microhabitats using a Tukey Honest Significant Differences (TukeyHSD) but also if the singing males were randomly distributed across the vegetation strata with a Chi-Square Test. The statistical analyses were done with R Studio version 1.0.153. (R Core Team 2017) with the package *lme4* (Bates *et al.* 2015).

Results

Method 1 (transect)

During the two first days, we found 40 singing *G. sibiricus* (distributed as follow in the different strata: 19 in small herbaceous, 9 in tall herbaceous, 6 on rocks, 4 in shrub and 2 on bare soil).

Singing males were mostly found in microhabitats with a temperature ranging from 18.5 °C to 45.75 °C (Figure 1A), and with a mean temperature of 28.24 °C (GLMM: 0.66 ± 0.25, p-value = 0.008) (Figure 1B). We found that the temperatures in the different vegetation strata were highly heterogeneous ranging from 12.4 °C to 69 °C and that mean temperatures for each strata were significantly different from each other with exception from shrub and tall herbaceous strata, for which the difference was not significant (Figure 1C). In addition, we

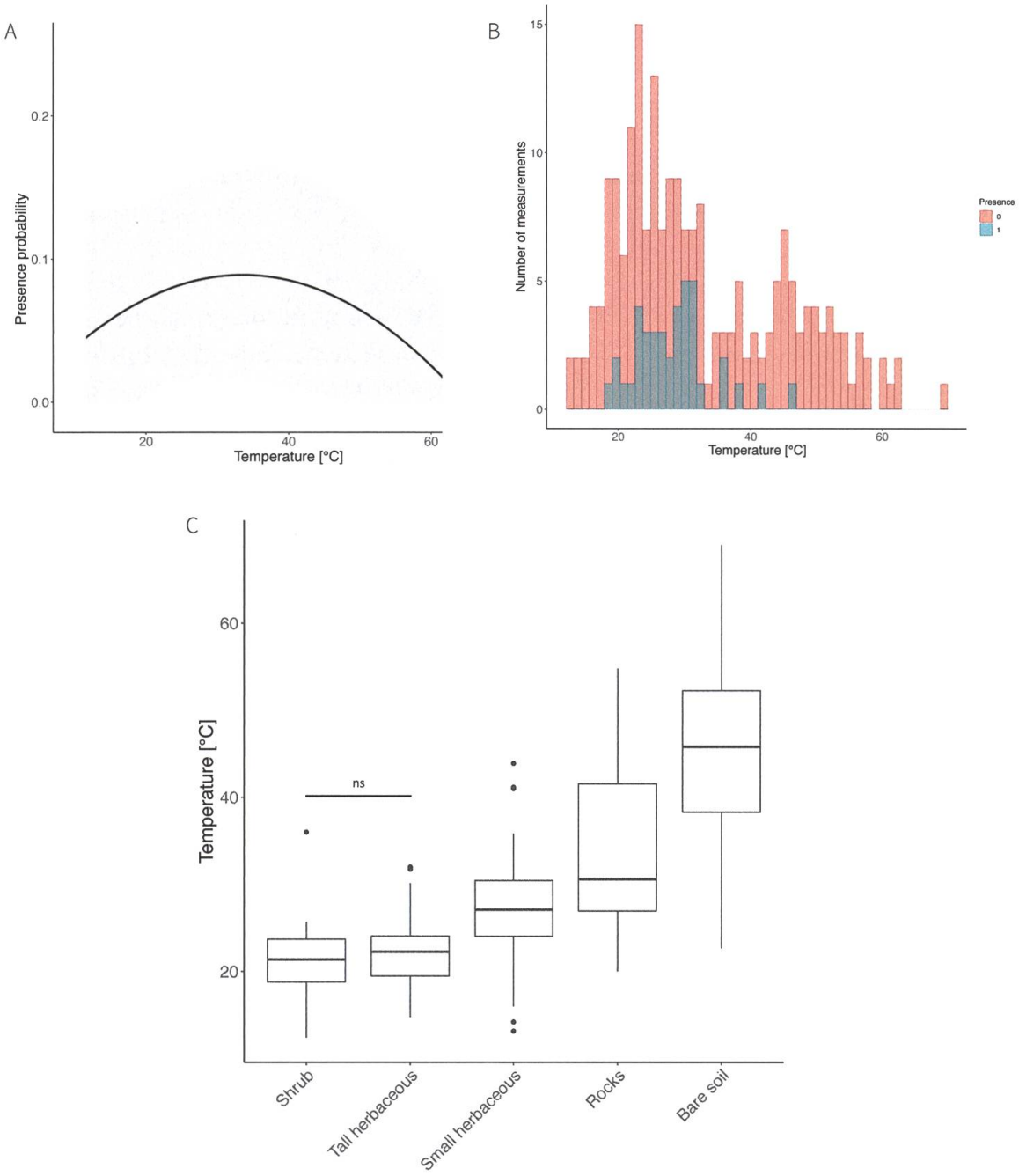

Figure 1. Probability to find *Gomphocerus sibiricus* according to the site temperature with the transect method (method 1). Response curve from a Generalized Linear Mixed Model (GLMM), the grey area corresponds to the CI 95 % (A), number of measurements according to temperature, presences in blue and absences in red (B), temperature in each vegetation stratum (C). All strata had a significantly different ($p < 0.05$) mean temperature with exception of the shrub and tall herbaceous strata.

found that the stridulating males were more often singing in the small herbaceous stratum than expected (Chi-Square Test; X-squared = 15.975, df = 4, p-value = 0.003).

Method 2 (grid)

During the third day, we recorded the temperature around 14 singing *G. sibiricus*. These measures showed that males select places to sing with temperature between 19.45 °C to 37.10 °C, with a mean at 28.47 °C and that it was significantly different from the background temperature (0.94 ± 0.43, p-value = 0.03).

Discussion

In this study, we found that stridulating *G. sibiricus* males mostly occupy locations with a temperature of 28 °C in small herbaceous plants even if they have a large choice of temperature ranging from 12.4 °C to 69 °C (Figure 1A) associated to various vegetation strata (Figure 1C).

Males' mating success could be greatly influenced by the stridulation site choice since females prefer some variation in the song range (Kindle *et al.* 2006), which is influenced by temperature (Souroukis *et al.* 1992, Walker & Cade 2003). But males could also be influenced by other factors, such as the proximity to open spaces to be easily heard and found by females or in the contrary more hidden places to avoid predation. It is not clear if the hypothetical optimal temperature we observed is the preferred stridulating temperature for the males or if it results of a trade-off between mating success and predation risk. Further studies should be performed to disentangle the effects of temperature and vegetation strata with an artificial manipulation of these parameters. Stridulations from males kept at different temperatures should be presented to females to investigate their preferences. Such experiment would help understand at which temperature males should stridulate for maximizing their attractiveness to females, and thus possibly highlight a trade-off in the case females' preferences doesn't match males' optimal stridulation temperature.

The presence of particular microhabitats could be important for other aspects of *G. sibiricus* life stage. Further studies could underline the importance of habitat heterogeneity, or at least the importance of some particular vegetation strata to permit *G. sibiricus* to complete its life cycle and could be a key point in the presence of this species.

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