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SHORT COMMUNICATION

Body temperatures in *Sympecma paedisca* (Zygoptera, Lestidae) in the autumn in the Central Ukraine

Stanislav N. Gorb*

Functional Morphology and Biomechanics, Zoological Institute, Kiel University, Kiel, Germany

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This short communication reports on the warming ability of the damselfly *Sympecma paedisca*, which is known for its winter hibernation and tolerance to low temperatures. The data were collected using an infrared camera in late September on two sunny days (air temperature 15–17°C) in the vicinity of Kyiv, Central Ukraine. The obtained data show that the thorax was almost always the warmest part of the body (up to 21°C in comparison to 17–18°C of the substrates damselflies were resting on and surrounding living plants). This indicates that the animals, in addition to sun, use their thoracic musculature to warm their bodies up. There was a clear correlation between thorax temperature and the temperature of both the head and abdomen, which means the warmed up thorax can transport part of its heat to other parts of the body by using their circulatory system.

Keywords: hibernation; temperature; body warming; damselfly; dragonfly; Odonata

Introduction

Sympecma paedisca and *S. fusca* are two damselfly species capable of overwintering at the imago stage in a temperate climate (Donath, 1981; Jödicke & Mitamura, 1995; Rademacher, 1998; Ruiter & Manger, 2007; Stalder, 2014), and their imagoes are capable of withstanding low temperatures even below the water freezing point. Behaviour of hibernating individuals has been previously described in numerous reports (Gorb, 1994; Hiemeyer, Miller & Miller, 2001; Tiefenbrunner, 1990). In autumn and winter, adult damselflies usually stay exposed in the shore vegetation of their breeding waters and also surrounding vegetation, sometimes at the distance of up to 1 km from the water bodies (Gorb, 1994). At low temperatures they can go deeper into grass and litter. Often they were observed sitting vertically or horizontally on the plant stems and leaves completely exposed to sun, wind, rain and snow (Hiemeyer et al., 2001). Even after exposure to snowing and freezing, after the ambient temperatures increase above 0°C the individuals are able to move, and at ambient temperatures of about 15°C they can fly.

The hibernation phase also has some thermoregulatory adaptations. For example, these damselflies are capable of orienting themselves on the grass substrate, in order to expose their wings and body in a manner resulting in an increase of the body temperature due to the improved exposure to the sun's warmth (Tiefenbrunner, 1990). It has often been observed that in autumn and winter on sunny days, the animals can come out of their grass shelters, crawl over the vegetation,

*Email: sgorb@zoologie.uni-kiel.de

warm themselves further and even hunt prey (Gorb, 1994). The present small and rather preliminary account reports on the observation of sun-exposed *Sympecma paedisca* damselflies in the autumn after a rather cold night (about 5–6°C). For this purpose, I applied an infrared camera technique, which has previously been used in studies of odonate thermoregulation (Svensson, 2012; Tsubaki et al., 2010). The images obtained allowed me to compare different parts of the body in *S. paedisca* and corresponding substrates. These results contribute to the understanding of physiological and behavioural adaptations of hibernating damselflies.

Materials and methods

The observations and images were made at Hodoseevka village, 20 km from Kyiv, Central Ukraine on 28–29 September 2011, both sunny days, at 10:00–12:00 and air temperature of 15–17°C. The preceding nights were rather cool (5–6°C). Air temperatures were measured using a thermometer, but temperatures of nearby objects, which were slightly different in every single IR image, were defined by using thermal imaging camera.

For IR imaging we used a thermal imaging camera (Trotec IC 080 V, Heisenberg, Germany). In all, we took 22 good quality images of different individuals in two days, which were used for statistical analysis. For the analysis, four randomly selected pixel areas of approximately 200 µm diameter were taken and averaged from each body part (head, thorax, abdomen), substrate (where the damselfly was sitting) and surrounding vegetation (surrounding or ambient temperature). The same procedure was made for each single image. For the statistical analysis, the temperature data obtained from all images were pooled together and then compared for each body part.

Results and discussion

Thermoregulation, and especially regulation of the thoracic muscle temperature, has been investigated in a number of anisopteran dragonfly species, but is poorly known in small zygopterans. The present study is a trial to get some data on representatives of small zygopterans. Measurements of the temperatures of the thorax, head and abdomen in many anisopteran species indicate that both thorax and head temperatures are relatively independent of air temperature (May, 1995a, 1995b, 2017). The obtained data on *Sympecma paedisca* showed that damselflies were already warmed up and capable of flight at relatively low ambient temperature. A very striking but not surprising result was that the thorax was almost always the warmest part of the body (Figure 1). This might indicate that the damselflies use their thoracic musculature to warm their bodies up in addition to the effect of the solar irradiation. Also, strong differences were revealed between the temperature of the substrate, where animals were perched, and the thoracic temperature. This supports the above suggestion about active warming up, especially because some substrates were living plants with cells still containing water and capable of passive warming due to their exposure to the sunlight. The head, thorax, abdomen temperatures and those of the substrate and surroundings did significantly differ from each other (Figure 2). On some IR images (Figure 1, lower left), the pterostigma was distinguishable, usually having a range of temperatures comparable with those of both the head and abdomen. The surrounding vegetation had much lower temperatures than any of three studied parts of the damselfly body: the difference was up to 3–5°C (Figure 2).

Similar to previous studies on anisopterans (May, 1995a, 1995b, 2017), thorax, head and abdomen temperatures were independent of the surrounding temperatures (Figure 3A; Table 1). There was a clear relationship between the thorax temperature and that of the head and abdomen

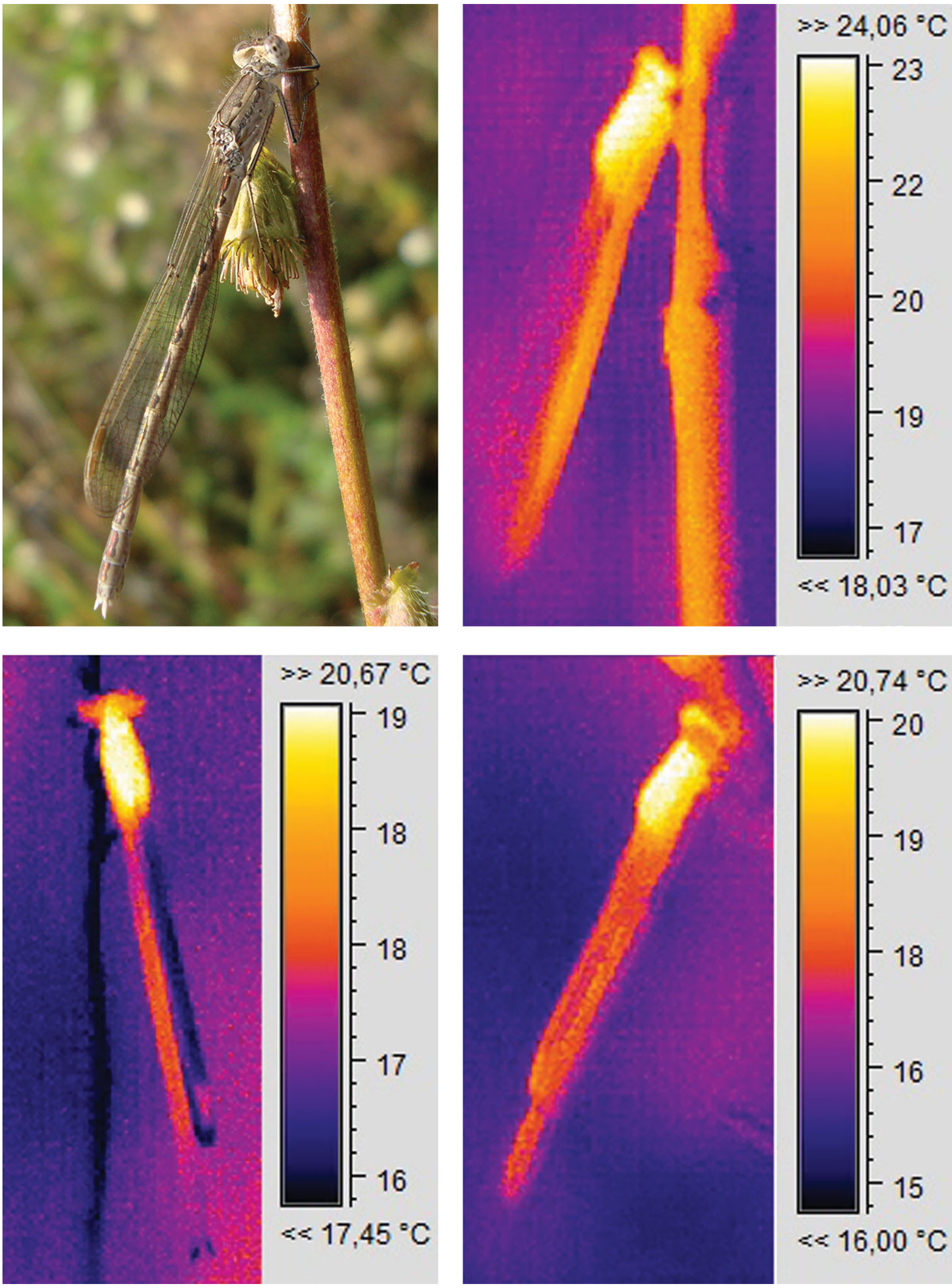

Figure 1. *Sympecma paedisca*, left upper image is the photograph taken at the study site and the three other images are examples of collected thermoimages, each showing the temperature map of the damselfly body. This kind of image was later used for comparison between temperatures of different body parts and natural substrates.

(Figure 3B, C; Table 1), which means that the warmed up thorax can transport part of its heat to the other parts of the body by the use of the circulation system (Heinrich, 1993; Kolev, Gorb, Schilling, & Riemer, 2001). Whether *S. paedisca* uses trembling of thoracic musculature (endothermic heating) for warming up, remains unclear. We cannot exclude that animals warm up due to their active flight. As mentioned above, Anisoptera are capable of elevating

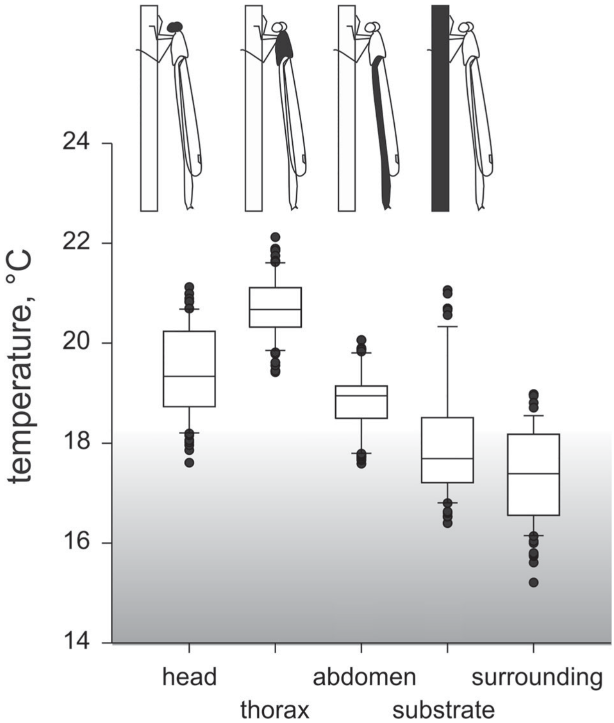

Figure 2. Results of the temperature analysis of the thermoimages, one-way ANOVA (F = 162.4, df = 4, $p < 0.001$). All sites are significantly different in their temperatures from each other at the level of $p < 0.001$ (all pairwise multiple comparison procedure – Tukey test).

Table 1. Pearson correlation coefficient (bold) between temperatures measured at different sites.

	Abdomen	Head	Substrate	Surrounding
Thorax	**0.772** $p < 0.001$	**0.557** $p < 0.001$	**0.682** $p < 0.001$	**–0.047** $p = 0.675$
Abdomen		**0.642** $p < 0.001$	**0.656** $p < 0.001$	**0.215** $p = 0.054$
Head			**0.643** $p < 0.001$	**0.041** $p = 0.717$
Substrate				**–0.319** $p = 0.004$

thoracic temperature, and that is why larger species are better able to maintain a constant body temperature (Sformo & Doak, 2006; May, 2017). In conditions of low external temperature, as in the case described here, it is expected that the thorax is usually warmer due to its endothermic maintenance. This is especially interesting to observe in a small zygopteran species.

Odonata often use behavioural thermoregulation including variations in body and wing postures and in perch substrate choice (May, 2017). This is certainly the case for *S. paedisca* (Tiefenbrunner, 1990), which by the combined use of behavioural adaptations, solar irradiation and endothermic thermoregulation is capable of an extreme expansion of its activity period in spring and autumn in comparison to the majority of other odonates living in the same habitats and of winter hibernation (Donath, 1981; Jödicke & Mitamura, 1995; Rademacher, 1998; Ruiter & Manger, 2007; Stalder, 2014).

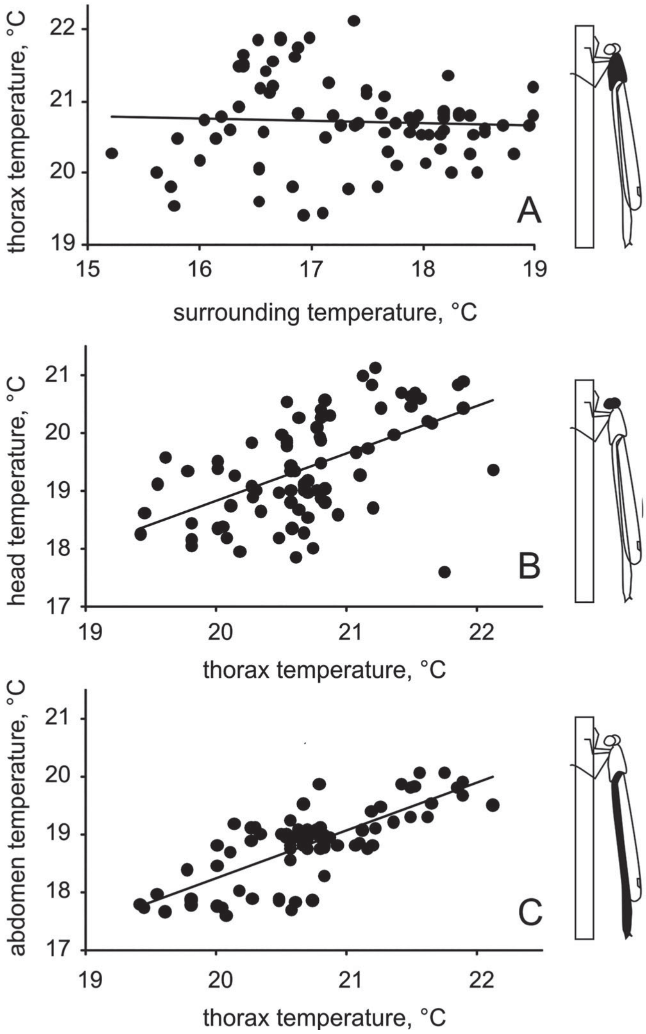

Figure 3. Relationship between temperatures measured at different sites (linear regression analysis). (A) Between surrounding temperature and damselfly thorax, *thorax* = 21.250 – (0.0308 × *surrounding*), $R^2 = 0.002$, ANOVA: $F = 0.177$, $p = 0.675$. (B) Between damselfly thorax and head, *head* = 2.451 + (0.819 × *thorax*), $R^2 = 0.310$, ANOVA: $F = 35.6$, $p < 0.001$. (C) Between damselfly thorax and abdomen, *abdomen* = 1.725 + (0.826 × *thorax*), $R^2 = 0.597$, ANOVA: $F = 116.8$, $p < 0.001$.

To sum up, the rather preliminary results presented above show that on sunny autumn days, when surrounding temperatures reach the limit (15°C) at which *Sympecma* damselflies can fly (Tiefenbrunner, 1990), animals are capable of further warming up their thoracic temperatures up to 21°C. It was previously reported that anisopterans, especially in the cooler regions, are capable of activity at ambient temperatures of approximately 14°C by employing different thermal strategies: lowering minimum flight temperature and enhancing physiological heat production (Sformo & Doak, 2006). The exposure to the sun presumably contributes to the warming up process, but this alone cannot explain such comparatively high thoracic temperatures measured in small *S. paedisca*, and that is why we assume an additional contribution of muscle activity.

The use of IR camera with a macro-lens is a very promising non-invasive method for studying odonate thermoregulation in the future. In future studies, it would be especially interesting to obtain information about the dynamics of warming up and cooling down in *Sympecma* damselflies, as well as to measure their body temperature in winter at air temperatures below 0°C.

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