

1 **Biogeographic position and body size jointly set lower**
2 **thermal limits of wandering spiders**

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11 **Abstract**

12 Most species encounter large variations in abiotic conditions along their distribution
13 range. Climate, and in particular temperature, varies along clinal gradients, which
14 determines phenotypic plasticity, local adaptations and associated physiological
15 responses of most terrestrial ectotherms, such as insects and spiders. This study aimed
16 to determine how the biogeographic position of populations and the body size of two
17 wandering spiders set their limits of cold (freezing) resistance. Using an ad-hoc design,
18 we sampled relatively large numbers of individuals from four populations of *Dolomedes*
19 *fimbriatus* and one population of the sister species *Dolomedes plantarius* originating
20 from contrasting climatic areas (temperate and continental climate), and compared their
21 supercooling ability as an indicator of cold resistance. Results indicated that spiders
22 from northern (continental) populations had higher cold resistance than spiders from a
23 southern (temperate) populations. Larger spiders had a lower supercooling ability in
24 northern populations. The red-listed and rarest *D. plantarius* was slightly less cold-
25 tolerant than the more common *D. fimbriatus*, and this might be of importance in a
26 context of climate change that could imply colder overwintering habitats in the north due
27 to reduced snow cover protection.

28 **Keywords:** Supercooling ability; fishing spiders; freezing; climate change; *Dolomedes*

29 **Introduction**

30 The ability of a species to cope with variations in abiotic conditions influences its
31 distribution range (Gaston 2003). Abiotic factors, and among them temperature, shape
32 the geographic range of ectotherm species, and this is even more relevant in the
33 context of global warming (Somero 2012, Addo-Bediako et al. 2000). Some ectotherms
34 survive freezing and are freeze tolerant whereas other ectotherms are freeze intolerant.
35 Freezing tolerant species, like some alpine species, tend to freeze at relatively high
36 subzero temperatures with ice nucleators and cryoprotectants, inducing and protecting
37 against freezing stress respectively, instead of having high supercooling abilities, i.e.
38 low supercooling point (SCP) (Duman 2001, Bale 2002, Duman et al. 2004). Freeze
39 intolerant arthropods, which include freeze-avoidant, chill tolerant, chill-susceptible and
40 opportunistic-survival classes, can exhibit deep supercooling ability, ranging from -15 to
41 -25°C (Danks 2004), by producing polyols and antifreeze proteins (Duman 2001, Bale
42 2002).

43 Many different measures are used to illustrate the thermal performance of populations
44 (Sinclair et al. 2015). It could be depicted by a thermal performance curve representing
45 how a temperature gradient influences arthropod activity (Sinclair et al. 2012, 2015). As
46 the estimation of thermal performances is influenced by many factors such as
47 phenotypic plasticity (Schulte et al. 2011) or evolutionary adaptation (Jensen et al.
48 2019), measuring an anchor point like the SCP is useful to assess the cold tolerance

49 class of species. Indeed, the SCP represents the lower lethal temperature (LLT) for
50 freezing-avoidant species and is still a useful indicator for chill-tolerant species as SCP
51 and LLT are almost similar for them (Bale 1996). However, many ectotherms classified
52 as chill-susceptible or opportunistic-survival, die at temperatures well above SCP, the
53 latter being less resistant than the former (Overgaard and MacMillan 2017, Bale 2002).
54 Even though the ecological value of the SCP has been debated (Renault et al. 2002,
55 Ditrich et al. 2018), it is still a useful metric to explore and describe the cold tolerance
56 strategy of poorly studied species, such as spiders (Sinclair et al. 2015).

57 Latitude and winter conditions influence the temperature gap between the SCP and the
58 lower lethal temperature (Addo-Bediako et al. 2000, Vernon and Vannier 2002). Indeed,
59 based on cold hardiness strategies defined by Bale (1996), opportunistic-survival
60 animals are mainly found in tropical and semi-tropical regions, chill susceptible and chill-
61 tolerant in temperate and sub-polar regions and freeze avoidant in region with severe
62 cold winter conditions.

63 Body size influences and is influenced by the animal's stage, its body fat content or the
64 concentration of ice-nucleating bacteria, which affect the SCP (David and Vannier 1996,
65 Johnston and Lee 1990, Colinet et al. 2007). The size of animals also changes along
66 latitudinal and altitudinal clines. Both an increase and a decrease of body size towards
67 northern latitude were observed and theorised under the Bergmann and converse
68 Bergmann rules respectively (Blanckenhorn and Demont 2004). For ectotherms, these
69 two rules were first opposed (Voorhies 1996, Mousseau 1997) but it seems that both

70 larger and smaller individuals at northern latitudes is possible and the two rules are
71 eventually not exclusive (Blanckenhorn and Demont 2004), possibly co-existing in close
72 species (e.g. in arctic wolf spiders, see Ameline et al. 2018). The latitudinal size cline is
73 of importance as body size also influences cold hardiness (Ansart et al. 2014), e.g. with
74 smaller arthropods having better supercooling capabilities than larger ones (Sømme
75 1982, David et al. 1996, Colinet et al. 2007, Sinclair et al. 2009). Hence, a negative
76 relationship between ectotherms size and the ability to supercool has been reported
77 (Lee and Costanzo 1998). Consequently, smaller individuals could benefit from colder
78 temperatures under harsher winter conditions at northern latitudes.

79 Most studies investigating latitudinal clinal changes of arthropods' physiological
80 tolerance focused on differences between species rather than among populations of the
81 same species (Spicer and Gaston 1999 but see, e.g. Jensen et al. 2019). Physiological
82 tolerance is a basal trait in arthropods, but it has evolved many times (Sinclair et al.
83 2003). Most of the knowledge on cold tolerance of arthropods comes from the study of
84 insects, and different mechanisms might influence the cold hardiness of insects and
85 arachnids. Indeed, Anthony and Sinclair (2019) showed divergent cryoprotective
86 dehydration, the action of losing water by evaporation at low temperature, between
87 insects and arachnids and the absence of coma under hypoxic conditions is also
88 remarkable in spiders (Pétillon et al. 2009). To our knowledge, not all spiders are
89 freezing tolerant (Nentwig 2012). The same cold hardiness classes are used to

90 categorise freezing intolerance of spiders and insects. Indeed, some spiders are freeze-
91 avoidant, others chill-tolerant or chill susceptible (Kirchner 1973, Anthony et al. 2019).

92 Although latitudinal variations in the cold hardiness of arachnids have been the subject
93 of recent attention (e.g. Anthony et al. 2019), studies comparing populations within
94 species are lacking (but see e.g. Murphy et al. 2008), this despite the recognised
95 importance of comparative approaches (e.g. see Ansart et al. 2014). Tough sampling
96 conditions at high latitude in the northern hemisphere may limit sampling of a sufficient
97 number of individuals and thus prevent studies from considering the northern part of a
98 species range.

99 In this study, we assessed the variation in cold resistance, estimated through SCP
100 ability of different populations and species of fishing spiders (Araneae, Pisauridae) with
101 contrasted distributions. We hypothesised that (i) northern populations of *Dolomedes*
102 *fimbriatus* have lower SCP values than southern populations, (ii) the size of spider in the
103 north is positively related to the SCP, and (iii) the species reaching the northern
104 latitudes (here *D. fimbriatus*) has lower SCP values than the more southern limited
105 species (*D. plantarius*: Monsimet et al. 2020), potentially due to their relatively smaller
106 body size. These hypotheses were experimentally tested in two European *Dolomedes*
107 species using relatively high numbers of field-collected spiders for representative results
108 and robust statistics.

109 **Materials and Methods**

110 **Case study species and sampling locations**

111 The fishing spiders, *Dolomedes plantarius* and *Dolomedes fimbriatus* are widespread in
112 Europe with a northern range limit in Fennoscandia. *D. plantarius* has a lower
113 population density and is red-listed at the European scale (World Conservation
114 Monitoring Centre 1996). The latitudinal contrast encompassed two different
115 biogeographic positions, characterizing two different climatic areas (continental, coded
116 C hereafter *versus* temperate, coded T). Individuals sampled at their range limit were
117 compared with others from a central latitude of the distribution. We sampled two sites
118 with *D. fimbriatus* and one site with *D. plantarius* in Fennoscandia (C1, C2 and C3; fig.
119 1), which characterise the northern population, subject to a continental climate. In
120 addition, we sampled two sites with *D. fimbriatus* in France (T1 and T2; fig. 1),
121 representing the centrally distributed populations exposed to a temperate climate. Given
122 the conservation status of *D. plantarius* in Europe, we chose to limit our sampling of this
123 species to the area where it is most abundant (Fennoscandia).

124 As the SCP is influenced by the developmental stage (Aitchison 1984, Anthony et al.
125 2019), we sampled only juvenile spiders of both sexes. The peak of the breeding
126 season of European *Dolomedes* is in late July (Smith 2000). Females keep egg sacs
127 several weeks before building a nursery web where eggs will hatch and from which
128 spiderlings will later spread out into the surroundings. Juvenile spiders overwinter, but

129 not adults, similarly to other species in the genus (Guarisco 2010). We sampled *D.*
130 *fimbriatus* by sweep-netting the vegetation on sunny and windless days. We sampled *D.*
131 *plantarius* on the water surface by visual hunting, and active hunting by perturbing the
132 water surface. We sampled, and latter tested the SCP of about 24 spiders at each
133 sampling site ($n = 24,24,21,26,24$ for C1,C2,C3,T1,T2 respectively, table 1).

134 **Measurement of the supercooling point**

135 To determine the SCP, we placed the spiders in centrifuge tubes, which were
136 submerged in a cryostat bath (Polystat CC3, Huber Kältemaschinenbau AG, Germany)
137 filled with heat transfer fluid (Thermofluid SilOil, Huber, Germany). The temperature of
138 the bath was slowly reduced at a rate of $0.5^{\circ}\text{C min}^{-1}$ to reach a target temperature of -
139 30°C . To monitor the temperature of the spiders, we placed a K-type thermocouple in
140 direct contact with the spider opisthosoma, secured with Parafilm® and connected to a
141 Testo 175T3 temperature data logger (Testo SE& Co., Germany). We recorded the
142 temperature every ten seconds. The SCP was defined as the temperature at the onset
143 of the freezing exotherm produced by the latent heat (see fig. 2 for representative
144 exotherms).

145 As the number of spiders tested per day was limited by the capacity of the instrument (4
146 spiders at a time), we later accounted for the time lag between capture and test in our
147 models (variable Diff).

148 **Measurement of spider body size**

149 We measured the spiders' body size after the SCP experiment to avoid injuring the
150 spiders and biasing the results. We took a picture of the spider' back together with a
151 measuring tape for measuring the body size later in the ImageJ software (Schneider et
152 al. 2012). We measured the highest length and largest width of the carapace (prosoma)
153 which are commonly used as proxy for whole body size, fitness and metabolic rate in
154 spiders (Jakob et al. 1996, Penell et al. 2018).

155 **Data treatment**

156 The carapace width and length were highly correlated ($\rho = 0.83$, Pearson correlation
157 test), so we used the carapace length as a proxy of body size (Jakob et al. 1996) and
158 referred to as body size hereafter.

159 **Comparison of SCP across latitudes (*D. fimbriatus*)**

160 We used the data from the four *D. fimbriatus* populations to assess the effect of latitude,
161 and called the model "modClim" in the following. We modelled the SCP with several
162 candidate linear models including predictor variables Diff (time between capture and
163 SCP measurements), site, climate (continental/temperate, as defined by the
164 biogeographic location), sex and body size. We also considered the interaction between
165 climate and body size and/or the interaction between body size and site (See appendix
166 1 for the list of candidate models).

167 **Comparison of SCP between species (northern populations)**

168 We used *D. fimbriatus* and *D. plantarius* from Scandinavia to compare the SCP of
169 species from northern populations, and called the model modSp in the following. We
170 modelled the SCP with several candidate linear models with variables Diff, site, species,
171 sex and body size, as well as the interaction between species and body size and/or the
172 interaction between body size and site (See appendix 2 for the list of candidate models).

173 **Statistical Analysis**

174 We used packages rstanarm (Goodrich et al. 2020), modelbased (Makowski et al. 2020)
175 and bayestestR (Makowski et al. 2019a) in R (R Core Team 2020) to fit the linear
176 models in a Bayesian framework. We used a normal distribution centred on 0 and a
177 standard deviation of 2.5 as weakly informative priors (rather than using flat priors, see
178 Gelman et al. 2008, Gelman and Shalizi 2013). We fitted the models using four chains
179 and 4000 iterations. We used leave-one-out-cross-validation value (LOO value) to
180 compare the predictive accuracy of fitted models, and to select the most accurate model
181 (Vehtari et al. 2017). We checked the convergence of the models both visually and by
182 making sure that Rhat value was not larger than 1.1 (Gelman and Rubin 1992).

183 Following Makowski et al. (2019b), we used the probability of direction (pd), which is the
184 probability that the posterior distribution of a parameter is strictly positive or negative, to
185 describe the existence of an effect of an explanatory variable. We used the percentage

186 of the full region of practical equivalence (ROPE) lower than 1% as an index of the
187 significance of an effect. We represented the uncertainty with a credible interval of 89%.

188 **Results**

189 **General results**

190 The SCP of the spiders varied from -2.6 to -16.4°C , with an average of $-7.8 \pm 2.3^{\circ}\text{C}$
191 ($n=119$). Fig. 2 shows typical cooling curves of *Dolomedes fimbriatus* (from C2) and
192 *Dolomedes plantarius* (from C3) with exotherms of about 8 and 6.5°C and a SCP of -9.3
193 and -7.5°C respectively. None of the spiders tested survived freezing.

194 The body size of juveniles of *D. plantarius* was on average $5.36 \pm 0.69\text{mm}$ while body
195 size of *D. plantarius* was $4.28 \pm 0.56\text{mm}$ in the South and $4.53 \pm 0.47\text{mm}$ in the South.

196 **Validation and selection of models**

197 All of our candidate models converged ($R_{\text{hat}} < 1.1$). According to LOO values, some
198 models were considered equivalent (Appendices 1 & 2). The modClim model with the
199 lowest LOO value and therefore the highest predictive power included variables Diff
200 (time between capture and test), climate, body size and the interactive effect of climate
201 and body size (table 2). For modSp model, the best model included Diff, species, body
202 size and the interactive effect of body size and species.

203 **Comparison of SCP across latitudes (*D. fimbriatus*)**

204 Regarding modClim (table 2), the SCP of individuals of southern and northern
205 populations significantly differed (pd = 99%, <1% in ROPE, fig. 3) and were $-6.6 \pm 2.3^\circ\text{C}$
206 (min. -11.5°C , max. -2.6°C ; n=50) and $-9.05 \pm 2.31^\circ\text{C}$ (min. -6.30°C , max. -2.30°C ,
207 n=48), respectively. The SCP significantly increased with the spider's body size (pd =
208 96%, <1% in ROPE, median = 8.4 [0.6; 16.5]), which means that larger spiders had
209 higher SCP than smaller spiders. The effect of spiders' body size on the SCP was
210 significantly different between the two climatic areas (pd = 98%, <1% in ROPE; fig. 4).
211 Namely, the SCP increased with the body size of spiders in the northern climate (pd =
212 96%, <1% in ROPE, median = 8.33 [0.15; 15.56]) while the relation between SCP and
213 body size in the South was not different from 0 (<1% in ROPE but pd < 90%).

214 **Comparison of SCP between species (northern populations)**

215 Regarding modSp (table 3), the SCP significantly increased with body size of both
216 species together (pd = 98%, <1% in ROPE, Median = 9.1 [2.0; 15.9]; fig. 5).
217 Nonetheless, the effect of body size on the SCP was not different between species (pd
218 = 93%). The SCPs of individuals of *D. plantarius* and *D. fimbriatus* of northern
219 populations likely differed (pd = 95%, 1%<ROPE<2.5%) and was -7.56 ± 0.32 (min.
220 -9.4°C , max. -4.4°C ; n=21) for *D. plantarius* (for *D. fimbriatus*, see above). We did not
221 find a significant effect of Diff for modSp (ROPE = 23%).

222 Discussion

223 Our study showed that the SCP of northern fishing spiders from a continental climate
224 was lower than the SCP of southern *Dolomedes* from a temperate climate. The SCP
225 was positively related to body size for both species, but this relationship differed
226 between the two climates for *D. fimbriatus*. Finally, we found that the SCP of
227 *Dolomedes fimbriatus* was slightly lower than that of *Dolomedes plantarius*.

228 The SCP of *D. fimbriatus* decreased with increasing latitude, while juveniles of the
229 species did not differ in size. In this study, we tested four populations from two
230 biogeographic locations which characterised different climates and latitudes along the
231 species distribution range. The northern populations, at the range limit, experience cold
232 winters with permanent snow cover, whereas the southern populations, from a more
233 central latitude of the range, experience warmer winters with only rarely a snow cover.
234 The northern and southern locations are characterised by temperate and continental
235 climate respectively (Kottek et al. 2006) and the corresponding range of temperatures
236 might explain the decrease in SCP towards the North. Indeed, temperature influences
237 cold hardiness in arthropods, including spiders (Nentwig 2012) and a poleward increase
238 in thermal tolerance is observed in many ectotherms (Sunday et al. 2011). An
239 acclimation to warmer temperatures, as for southern spiders, can also reduce the
240 tolerance to cold conditions (Jensen et al. 2019). At the same time, northern spiders
241 could benefit from their cold acclimation by being more active during cooler periods in

242 summer (Everatt et al. 2013). The diurnal range also differs along the latitudinal
243 gradient; i.e. northern populations stand more substantial variation in the diurnal activity
244 range.

245 The impact of diurnal activity range, together with temperature, are essential cues to
246 determine the cold resistance of ectotherm arthropods (e.g. soil dwelling collembolan
247 *Orchesella cincta* see Jensen et al. 2019, or Paaijmans et al. 2013, Seebacher et al.
248 2015). These might have impacted spiders differently at the time of our experiments
249 (late summer/ early autumn), as northern *Dolomedes* are confronted to earlier and
250 harsher winter. These two cues have been shown to impact the overwintering of
251 another *Dolomedes* species, from North America (*D. triton*; Spence and Zimmermann
252 1998), and might similarly impact the overwintering of *D. fimbriatus*. To our knowledge,
253 *Dolomedes* species are inactive during winter (Aitchison 1984). Schmidt (1957) noted
254 that *D. fimbriatus* overwinters twice before reaching the adult stage. He also noted that
255 juveniles spend the winter in dry vegetation at high strata, which is probably the
256 overwintering habitat of the southern spiders we tested here. However, the northern
257 *Dolomedes* we tested endure temperatures colder than the SCP measured in this study.
258 For this reason, we hypothesised that, similarly to *Dolomedes triton* in Canada (Spence
259 and Zimmermann 1998), spiderlings and juveniles overwinter under the snow. Indeed,
260 the temperature in the subnivean layer, which is between the soil surface and the base
261 of the snowpack, is warmer and more stable than the air temperature above the snow,
262 and protect species from temperatures lower than their SCP (Marchand 1982).

263 *Dolomedes*, like other spider species, are not freezing tolerant as none of the spiders
264 tested survived freezing. Cold-hardiness of *Dolomedes* is important for winter survival.
265 Based on the cold hardiness classification of Bale (1996) and Bale (2002) (see also
266 appendix 3 for a summarised classification), we hypothesise that *Dolomedes*, at least
267 from the northern populations, are either chill-susceptible or freeze-avoidant. The main
268 difference between these two cold hardiness classes is the ability to survive damages
269 caused by cold injuries. Freezing-avoidant species survive until freezing, while chill-
270 tolerant die sooner due to chill injuries. Spiders from a close family (*Pardosa*,
271 Lycosidae) at northern latitudes are from the same cold hardiness class (Anthony and
272 Sinclair 2019). Nonetheless, we only tested the SCP and more measurements, such as
273 the lower lethal temperature, would be necessary to define the cold hardiness class
274 more precisely. The cold hardiness class of *Dolomedes* might also vary between the
275 two biogeographic positions as demonstrated for the butterfly *Piries rapae* which is
276 either freeze-tolerant or freezing-avoidant depending on the latitude (Li and
277 Zachariassen 2007).

278 Even if *Dolomedes* from the two areas did not differ in body size, we found an overall
279 decrease of the SCP with increasing spider body size. Smaller individuals being more
280 cold tolerant than bigger ones is a general trend for ectotherm animals (e.g. for ants see
281 Hahn et al. (2008), for beetles see Johnston and Lee (1990)). This trend is also
282 observed for spiders with smaller instars being more tolerant to cold than larger

283 juveniles and adults (Almquist 1970, Bayram and Luff 1993), and it might explain our
284 extreme SCP measures down to $-16.8\text{ }^{\circ}\text{C}$ for one *D. fimbriatus* from Fennoscandia.

285 The decline in supercooling abilities with increasing latitude was nonetheless not
286 observed in southern *D. fimbriatus*. The size of southern spiders, that have higher SCP,
287 seemed to be less related to SCP. This difference in strategy between temperate and
288 colder habitats has been reported in other species from the closely-related family of
289 Lycosidae (Ameline et al. 2018). The northern spiders have a shortened breeding
290 season, which can impact life history traits such as body size (Bowden et al. 2015). The
291 smaller fishing spiders under continental climate could be advantaged as they can
292 survive colder winters. After the winter, northern fishing spiders could accelerate their
293 development because cold-adapted ectotherms have a higher metabolic rate in an
294 environment with limited energy (Sinclair et al. 2012).

295 We found slightly higher resistance to cold temperature in *D. fimbriatus* compared to *D.*
296 *plantarius* (for populations at similar latitudes), which might be partly due to the smaller
297 size of *D. fimbriatus*. In turn, this difference between species might explain the wider
298 northward distribution of *D. fimbriatus* compared to that of *D. plantarius*. It indeed
299 appears that specialist species are larger under harsher conditions because they are
300 more adapted to their environment (Ameline et al. 2018). A larger size implies a smaller
301 cold resistance here, which might be detrimental in this case. Nonetheless, the SCPs
302 measured in this study were close to those measured for phylogenetically close spiders

303 (from the same Lycosoidea superfamily) from northern latitudes (Anthony and Sinclair
304 2019). These values are considered as medium cold resistance (Nentwig 2012).

305 Climate change impacts spiders in various ways. At northern latitudes, subnivean layer
306 is supposedly a non-freezing environment with quite stable temperatures (Pruitt 1957)
307 but snow density and length of the snow season impacts the stability of these conditions
308 (Pauli et al. 2013, Bale and Hayward 2010). While air temperature increases with
309 climate change, the subnivean layer may become colder (Wipf and Rixen 2010). This
310 paradox is already negatively impacting invertebrates (Williams et al. 2015, Slatyer et al.
311 2017). Even though we found that fishing spiders from continental climate tolerated
312 colder temperatures than spiders from temperate climate, the lowest SCP was higher
313 than the lowest air temperature measured historically in Fennoscandia. A weakened
314 subnivean shelter could negatively impact northern populations and even more so for
315 the rare *D. plantarius* which is less cold resistant. Another impact of the increased
316 length of the snow free season could be a second clutch in northern *Dolomedes*, as
317 reported in the arctic Lycosidae *Pardosa glacialis* (Høye et al. 2020).

318 We found that the cold tolerance of fishing spiders varied among populations, between
319 climates and between species. Nonetheless, the difference in SCP between the two
320 species was not striking. Sample another population of *D. plantarius* could support the
321 slight difference found between species, but we tried to limit the impact of sampling on
322 populations of this red-listed species (World Conservation Monitoring Centre 1996).
323 Moreover, we assessed cold tolerance based on measuring the SCP only and from

324 spiders sampled in late summer / early autumn. Sampling *Dolomedes* is challenging
325 especially at northern latitudes in winter. Nonetheless, studying life history traits like
326 cold resistance is valuable to explore and predict the distribution of understudied
327 invertebrates (Mammola et al. 2020), especially by integrating ecophysiology of species.

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522 Tables

523 Table 1: Description of the climatic conditions at the sampling sites, based on the
524 Köppen-Geiger climate classification (Kottek et al. 2006). N: number of spiders tested;
525 SCP: mean SCP \pm SD; Length: mean length of the carapace \pm SD; Mean temp: annual
526 mean temperature; Diurnal range: mean diurnal range (extracted from Fick and Hijmans
527 (2017)).

Sites	Species	N	Country	Climate	SCP (°C)	Length (mm)	Mean Temp	Diurnal range
C1	<i>D. fimbriatus</i>	24	Norway	Continental	-9.08 \pm 0.45	4.13 \pm 0.52	2.56	9.50
C2	<i>D. fimbriatus</i>	24	Sweden	Continental	-9.06 \pm 0.4	4.43 \pm 0.56	5.52	8.54
C3	<i>D. plantarius</i>	21	Sweden	Continental	-7.56 \pm 0.32	5.36 \pm 0.69	6.05	7.78
T1	<i>D. fimbriatus</i>	26	France	Temperate	-7.78 \pm 0.4	4.62 \pm 0.46	11.62	7.03
T2	<i>D. fimbriatus</i>	24	France	Temperate	-5.39 \pm 0.4	4.44 \pm 0.48	11.14	6.30

528

529 Table 2: Parameter estimates of the most accurate model explaining the SCP values
530 between different climatic areas for *D. fimbriatus* (modClim, see appendix 1). CI: 89%
531 credible intervals, pd: probability of direction, ROPE: percentage of the full region of
532 practical equivalence. Diff: time difference between date of capture and date of test;
533 Temperature: climate variable (continental climate in the intercept); Temperate:Body
534 size: interactive effect of the climate and body size.

	Estimate	CI low	CI high	pd	ROPE (%)	Rhat
(Intercept)	-8.3	-12.3	-4.7	1.00	0.0	1.0
Diff	-0.3	-0.4	-0.2	1.00	23.1	1.0
Temperate	8.1	3.2	12.8	0.99	0.4	1.0
Body size	8.4	0.6	16.5	0.96	0.9	1.0
Temperate:Body size	-14.3	-24.7	-2.8	0.98	0.4	1.0

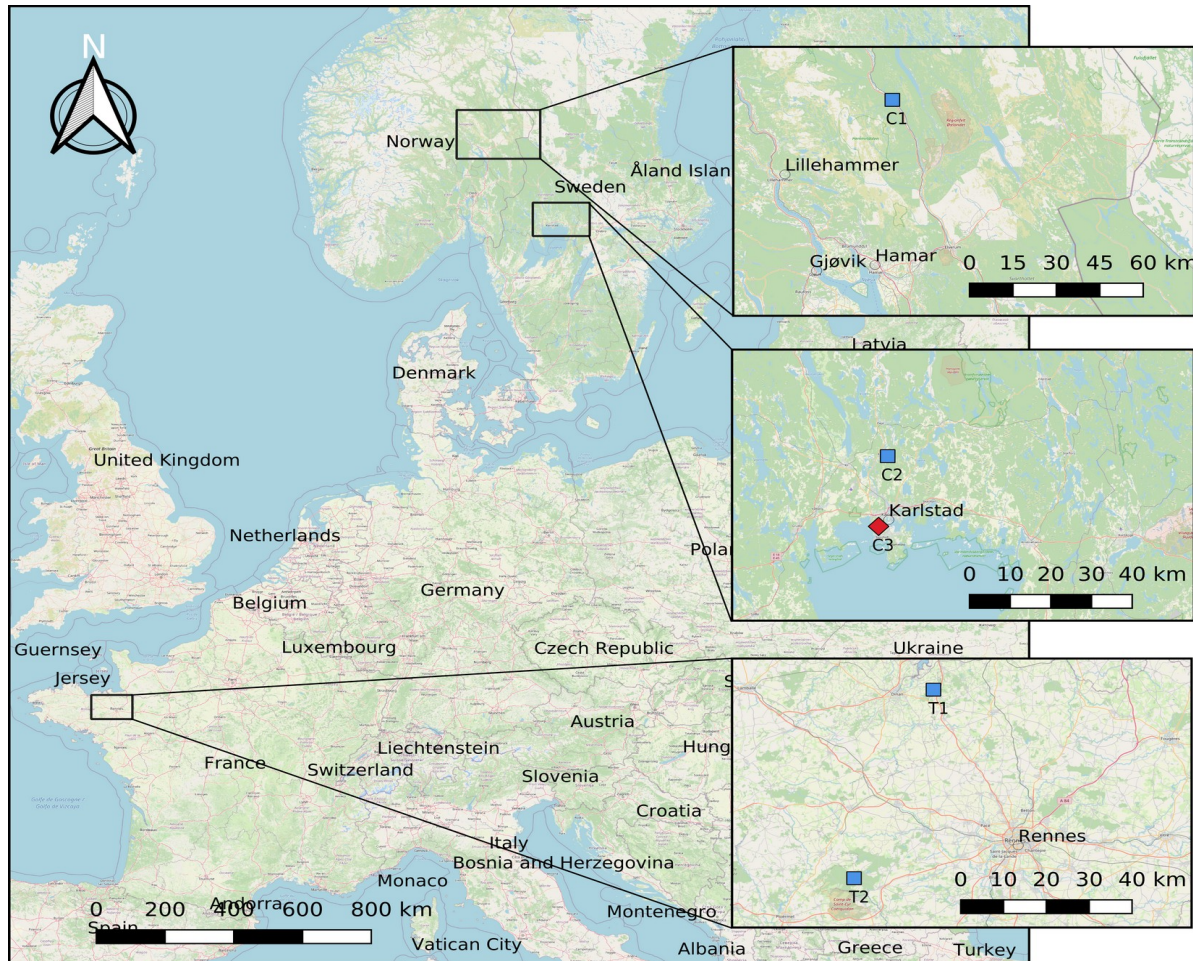
535

536 Table 3: Parameter estimates of the most accurate model explaining the SCP values
537 between the two species in continental climate (modSp, see appendix 2). CI: 89%
538 credible intervals, pd: probability of direction, ROPE: percentage of the full region of
539 practical equivalence. Diff: time difference between date of capture and date of test; *D.*
540 *plantarius*: species variable (*D. fimbriatus* in the intercept); *D. plantarius*:Body size:
541 interactive effect of species and body size.

	Estimate	CI low	CI high	pd	ROPE (%)	Rhat
(Intercept)	-9.77	-13.8	-5.6	1.00	0.0	1.0
Diff	-0.22	-0.4	-0.0	0.97	42.8	1.0
<i>D. plantarius</i>	4.80	0.1	9.4	0.95	1.6	1.0
Body size	9.10	2.0	15.9	0.98	0.5	1.0
<i>D. plantarius</i> :Body size	-8.65	-17.4	1.0	0.93	0.8	1.0

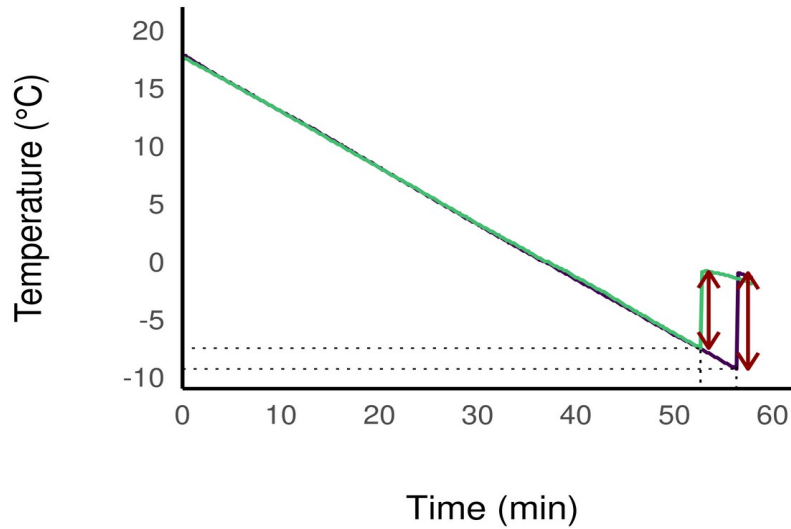
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543 Figures

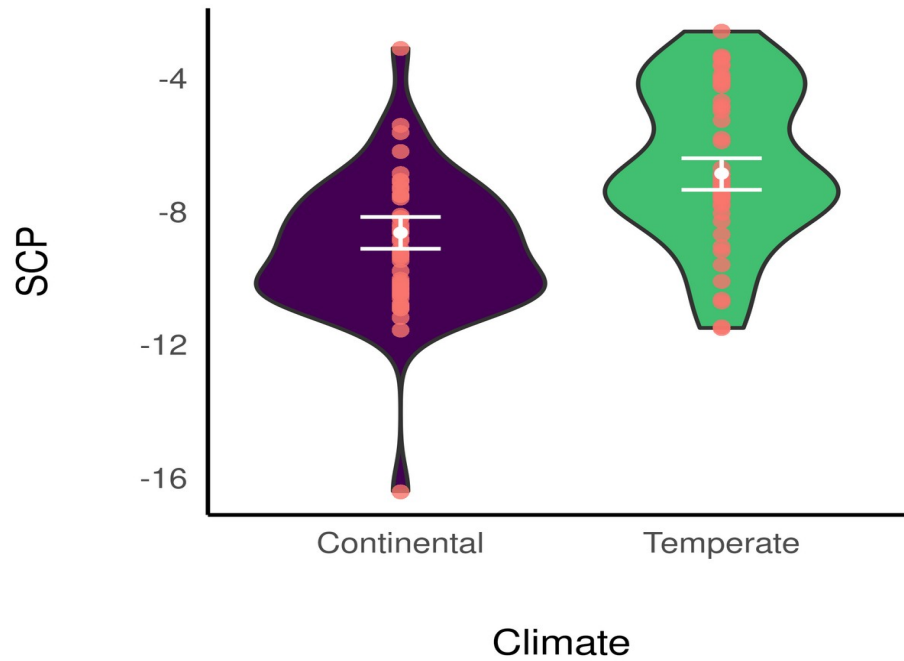


544 Figure 1: Location of sampling sites for *Dolomedes fimbriatus* (blue squares) and

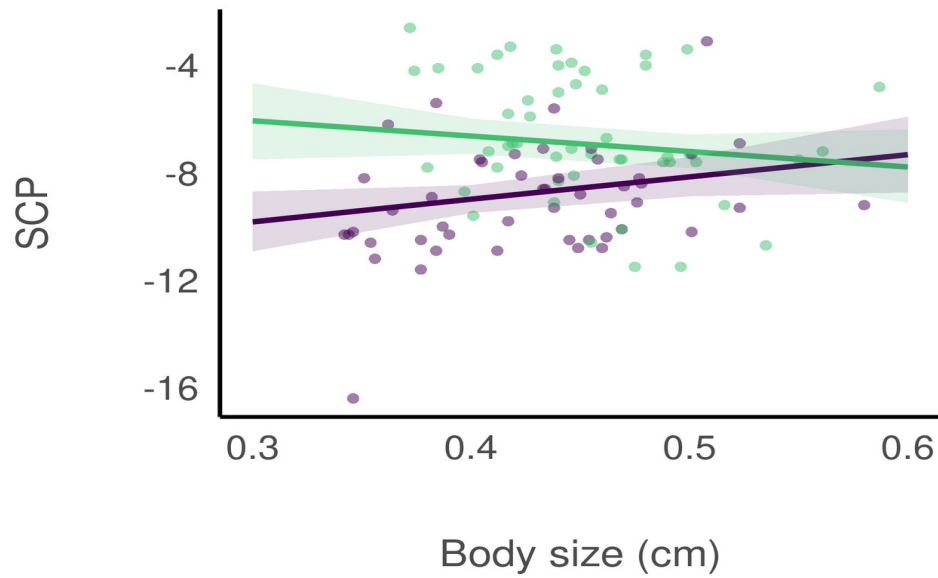
545 *Dolomedes plantarius* (red square) in France and Fennoscandia.



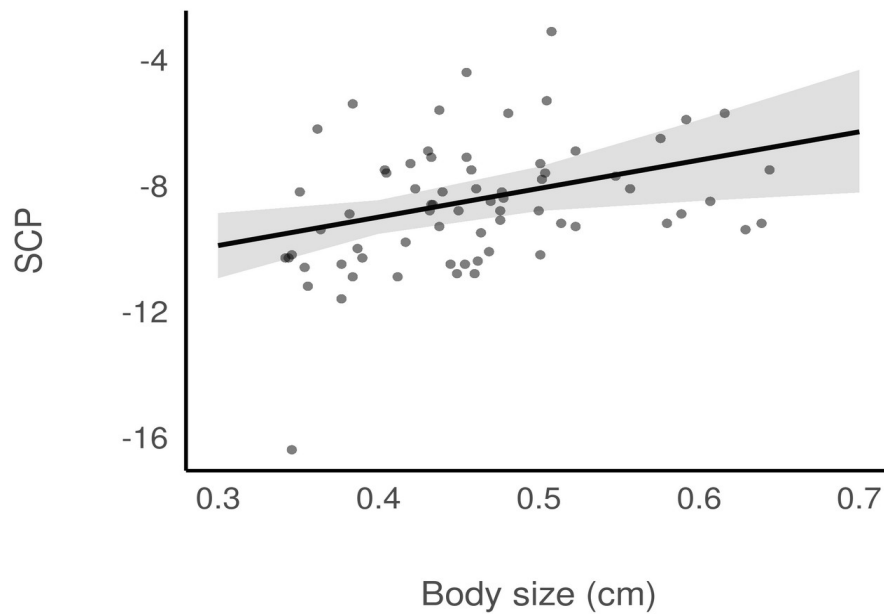
546 Figure 2: Cooling curves of *D. plantarius* (one spider from C3, in yellow) and *D.*
547 *fimbriatus* (one spider from C2, in purple) recorded during a cooling experiment. The
548 SCP (dotted line) is followed by the exotherm (dark-red arrows), a sudden increase in
549 the measured temperature due to the release of latent heat linked to the phase change
550 during freezing.



552 Figure 3: Marginal posterior means of SCP (white dot) estimated under modClim for the
553 two different climatic areas and its 89% credible interval (white bar). Red dots represent
554 the original data and the violin distributions represent a density plot.



555 Figure 4: Predicted effect of *D. fimbriatus* body size on the SCP, and its 89% credible
556 interval, for the two different climatic areas under modClim. Purple: predictions for the
557 continental climate, green: predictions for the temperate climate; dots represent original
558 data.



559 Figure 5: Predicted effect of body size of *D. plantarius* and *D. fimbriatus* on the SCP in
560 Scandinavia, and its 89% credible interval, under modSp. Dots represent original data.