Oikos

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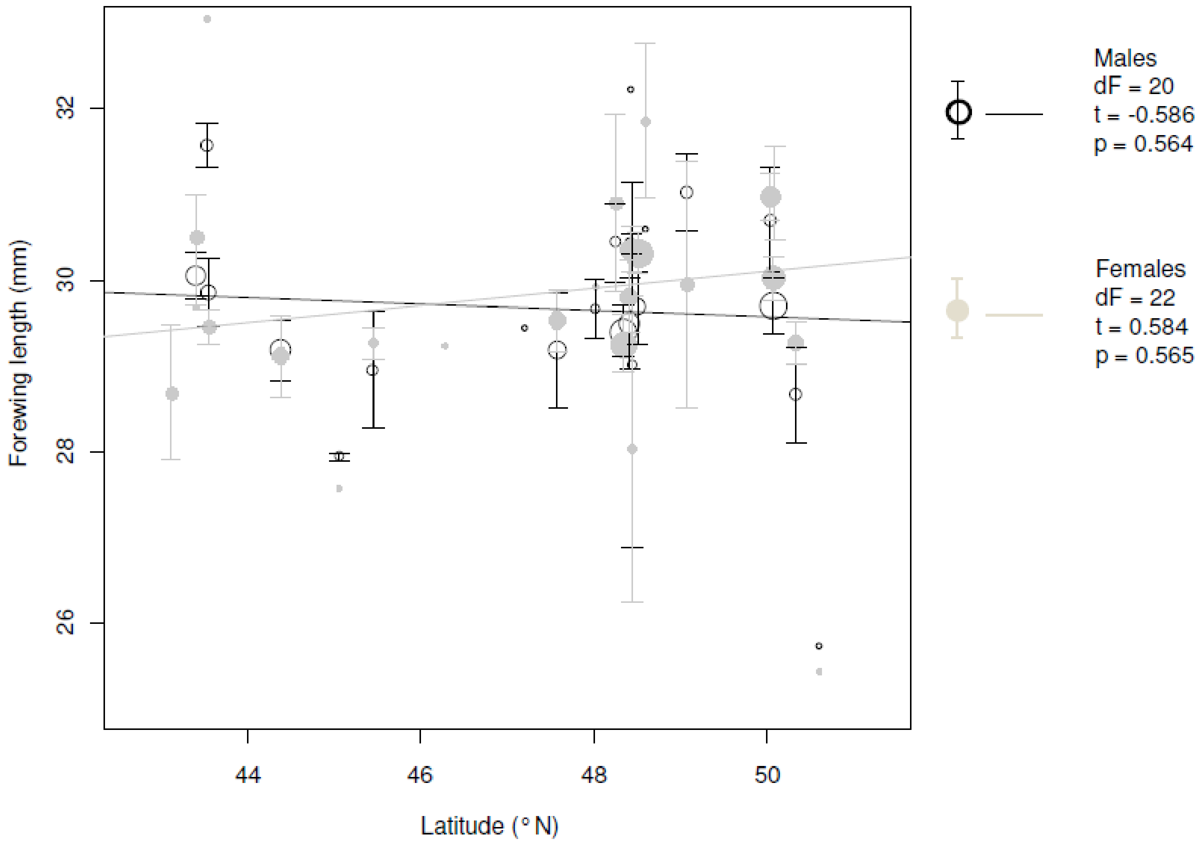
Ducatez, S., Baguette, M., Trochet, A., Chaput-Bardy, A., Legrand, D., Stevens, V. and Fréville, H. 2013. Flight endurance and heating rate vary with both latitude and habitat connectivity in a butterfly species. – Oikos 122: 601–611.

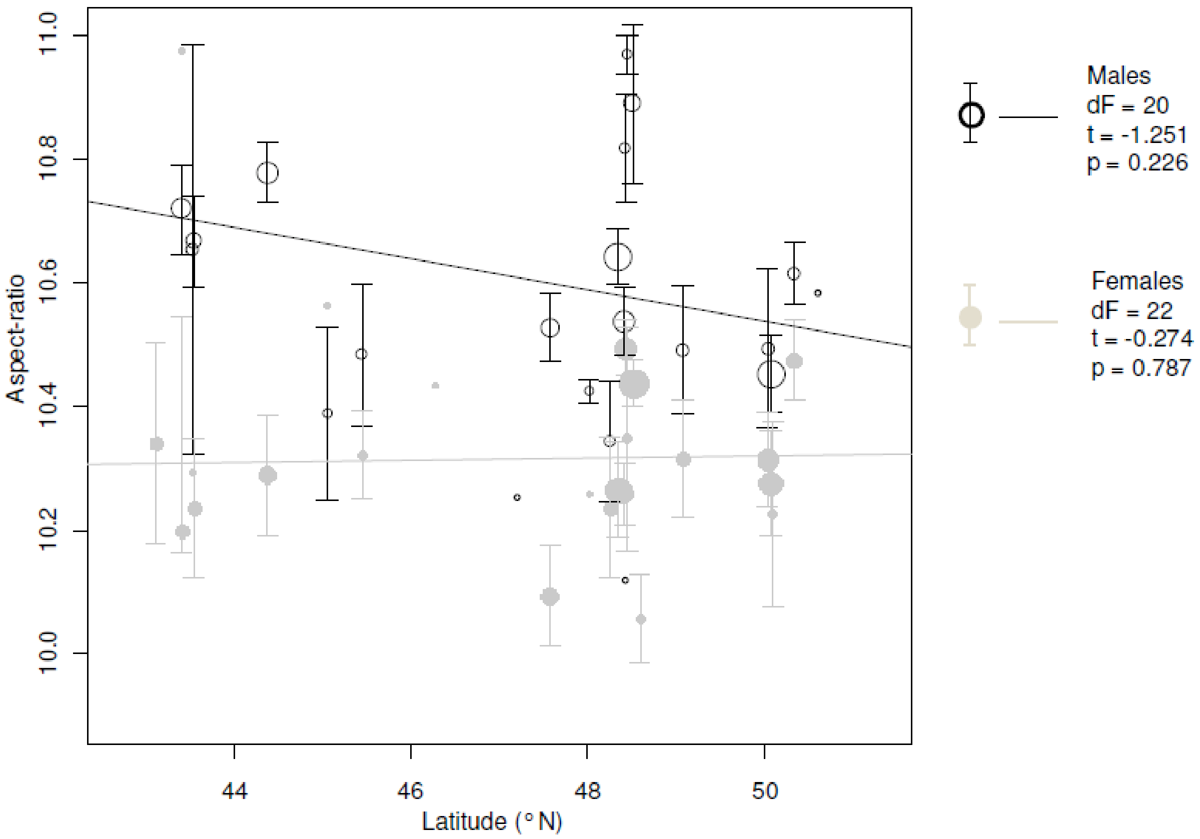
Appendix A1

Relationship between wing morphology (a): forewing length in mm; (b): aspect ratio, and latitude in *Pieris brassicae*. Each sampled site is characterized by the mean of individual forewing length or aspect-ratio (circle) and its standard error when sample size was larger than one. Circles are sized proportionally to sample size ranging from one to 20 individuals (see Table 1 for details). The linear relationship between flight endurance and latitude is plotted according to the model with site as a random factor. Empty black circles and lines = males; grey circles and lines = females.

(a)


Males
dF = 20
t = -0.586
p = 0.564
Females
dF = 22
t = 0.584
p = 0.565
Forewing length (mm)
Latitude (° N)
26
28
30
32
44
46
48
50

(b)


Aspect-ratio
11.0
10.8
10.6
10.4
10.2
10.0
44
46
48
50
Latitude (° N)
Males
dF = 20
t = -1.251
p = 0.226
Females
dF = 22
t = -0.274
p = 0.787

Appendix A2

Effects of latitude and habitat connectivity on flight endurance in Pieris brassicae, considering potential effects of wing morphology and heating rate: results of model averaging on linear mixed models with site as a random effect.

We directly evaluated the contribution of wing morphology (both aspect-ratio and wing length) and heating rate to latitudinal variation in flight endurance. To that aim, we conducted three additional analyses, using model selection according to AICc and model averaging methods on linear mixed models as described in methods; in addition to latitude, habitat area, the connectivity index, sex, site and their interactions, we successively added wing length, wing shape and heating rate, as well as their interactions as explanatory variables. We obtained the following results:

Response variable	n	Explanatory variable	Coefficient	SE	CI	weight
Flight endurance (wing length included as explanatory variable)	171	wing length	0.032	0.049	[-0.064; 0.129]	0.22
		Habitat area	0.150	0.182	[-0.228; 0.528]	0.26
		latitude	-0.252	0.065	[-0.381; -0.124]	1
		Sex	< 0.001	0.121	[-0.24; 0.239]	0.26
		Habitat area:sex	-0.268	0.121	[-0.506; -0.029]	0.26
Flight endurance (aspect-ratio included as explanatory variable)	171	wing shape	-0.276	0.245	[-0.760; 0.208]	0.40
		Habitat area	0.144	0.181	[-0.231; 0.520]	0.36
		latitude	-0.252	0.065	[-0.380; -0.124]	1
		Sex	0.046	0.142	[-0.234; 0.326]	0.36
		Habitat area:sex	-0.270	0.121	[-0.509; -0.032]	0.36
Flight endurance (heating rate included as explanatory variable)	108	Habitat area	0.109	0.237	[-0.399; 0.617]	0.30
		Heating rate	-0.084	0.086	[-0.254; 0.087]	0.15
		Latitude	0.216	0.201	[-0.216; 0.648]	0.27
		Sex	0.292	0.145	[0.004; 0.580]	0.89
		Habitat area:sex	-0.271	0.144	[-0.556; 0.014]	0.30

Wing length and wing shape had no significant effect on flight endurance, thus suggesting that the effects of latitude and habitat area on variation in flight endurance were not explained by variations in these variables. Similarly, heating rate was not included in any of the models with $\Delta AICc < 2$. This result might at first be surprising, provided that we detected a strong significant relationship between flight endurance and heating rate in laboratory raised individuals (n = 28 individuals from the 12th generation of breeding;

regression of flight endurance on heating rate after excluding the sex effect: $r^2 = 0.24$; $p = 0.009$). Here, however, we could only analyze data from 108 individuals originated from 16 sites where at least one butterfly had been tested for both flight endurance and heating rate. Such sample size may have limited the statistical power of a model testing the effects of such a large number of explanatory variables. Indeed, we only detected a significant effect of sex on flight endurance in this analysis, whereas flight endurance was also affected by latitude in other analyses based on a larger dataset (Table 2). Although heating rate might play an important role in shaping latitudinal variation in flight endurance, we believe that our dataset was not large enough to detect such an effect.

Appendix A3

Relationship between flight endurance and latitude in males and females of *Pieris brassicae*. Each sampled site is characterized by the mean of individual flight endurance (circle) and its standard error when sample size was larger than one. Circles are sized proportionally to sample size ranging from one to 13 individuals. The linear relationship between flight endurance and latitude is plotted according to the model with site as a random factor. Empty black circles and lines = males; grey circles and lines = females.