Ecography

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Supplementary material

Appendix 1

Wing morphology and mass measurements

Behavioral differences among individuals can result from differences in individual state (sensu Dingemanse and Wolf 2010; Houston and McNamara 1999), and particularly morphological features. In butterflies, wing morphology strongly influences flight capacity, and thus movement capacity (Dudley 2000; Berwaerts, Van Dyck and Aerts 2002). We measured wing morphology from a digital photography for each butterfly. A close-up of each butterfly was made on butterflies anaesthetized with nitrogen monoxide (using an Inject + Matic Sleeper TAS) and fixed between two transparent plastic pieces. Individuals were then photographed with a Nikon D300 digital camera equipped with a 105 mm lens using a decimeter to ensure comparability across all images. We first estimated for each individual an age index considering the wear of the wings (using the usual index from 1 to 4 used in Capture Mark Recapture experiments on butterflies: e.g. Baguette and Nève 1994). Each forewing was then extracted from the picture using the Gimp software (GNU Image Manipulation Program), and its surface and length were measured with the ImageJ software (U.S. National Institutes of Health, Bethesda, USA). We measured two variables which differently describe the morphology. First, we measured wing *aspect-ratio* (4*forewing length^2/forewing area, hereafter referred as *wing shape*) that has been shown to be a good proxy of flight capacity, individuals with small aspect-ratios being good flyers (Berwaerts, Van Dyck and Aerts 2002). Second, we measured *wing loading* estimated as the ratio of body mass to total wing area. This variable reflects the average pressure exerted on the surrounding air by the wings in non-accelerating flight. We measured butterflies dried body mass to the nearest 0.1 mg after extracting the wings and legs.

Effects of morphology on correlations between test scores

To test whether morphology might drive the correlations found between test scores, we added morphological variables in the different models we investigated. We used linear models with the score at one test as response variable, the score at another test as an explanatory variable, age, sex and species mobility rank as fixed variables, as well as aspect-ratio and wing loading. All second order interactions were also considered in the initial model, and we model-averaged parameter estimates, using the natural average method (Burnham and Anderson 2002) and the R package MuMIn (Grueber *et al*. 2011).

Results

Averaged model testing the relationship between greenhouse flight distance and vortex flight time

Explanatory variable	Estimate	SE	Adjusted SE	Z	p
sex	0.742	0.367	0.367	2.018	0.044
vortex flight time	0.005	0.009	0.009	0.535	0.593
sex * vortex flight time	-0.006	0.005	0.005	1.165	0.244
mobility rank	-0.188	0.222	0.223	0.843	0.400
mobility rank * sex	-0.336	0.197	0.198	1.693	0.090
mobility rank * vortex flight time	0.009	0.005	0.005	1.689	0.091
aspect-ratio	-0.048	0.069	0.070	0.682	0.495

Averaged model testing the relationship between tunnel distance and greenhouse flight distance

Explanatory variable	Estimate	SE	adjusted SE	Z	P-value
greenhouse flight distance	-0.151	0.361	0.361	0.419	0.675
mobility rank	-0.107	0.209	0.209	0.511	0.610
sex	0.164	0.116	0.117	1.411	0.158
greenhouse flight distance * mobility rank	0.233	0.122	0.123	1.887	0.059
wing-loading	-7.878	6.203	6.233	1.264	0.206

Averaged model testing the relationship between tunnel distance and vortex flight time

Explanatory variable	Estimate	SE	adjusted SE	Z	P
aspect-ratio	-0.191	0.173	0.174	1.100	0.271
mobility rank	-0.161	0.628	0.630	0.255	0.799
vortex flight time	-0.007	0.018	0.018	0.378	0.706
mobility rank * vortex flight time	0.014	0.004	0.004	3.385	<0.001
sex	0.790	1.279	1.283	0.616	0.538
wing-loading	-5.232	5.701	5.732	0.913	0.361
sex * aspect-ratio	-0.185	0.158	0.159	1.163	0.245
mobility rank * aspect-ratio	-0.105	0.134	0.135	0.775	0.438
vortex flight time * aspect-ratio	-0.003	0.004	0.004	0.704	0.482
sex * vortex flight time	-0.005	0.005	0.005	0.996	0.319

Bibliography

Berwaerts, K., Van Dyck, H. and Aerts, P. 2002. Does flight morphology relate to flight performance? An experimental test with the butterfly *Pararge aegeria*. - Funct. Ecol.: 16: 484-491.

Burnham, K.P. and Anderson, D.R. 2002. Model selection and multimodel inference: a practical information - theoretic approach. - 2nd edn. New York, USA: Springer.

Dingemanse, N.J. and Wolf, M. 2010. Recent models for adaptive personality differences: a review. - Phil. Trans. R. Soc. B 365: 3947-3958.

Dudley, R. 2000. The Biomechanics of Insect Flight. - Princeton, USA: Princeton University Press.

Grueber, C.E., Nakagawa, S., Laws, R.J. and Jamieson, I.G. 2011. Multimodel inference in ecology and evolution: challenges and solutions. - J. Evol. Biol. 24: 699-711.

Houston, A.I. and McNamara, J.M. 1999. Models of adaptive behaviour. - Cambridge, UK: Cambridge University Press.

Appendix 2

Interspecific differences in tunnel and heating rate scores. Between-species comparisons (Wilcoxon tests) are presented for models where the species effect was significant or marginally significant (Table 1).

	M. jurtina				*P. aegeria*				*P. rapae*			
	tunnel distance		heating rate		tunnel distance		heating rate		tunnel distance		heating rate	
species	W	P	W	P	W	p	W	p	W	p	W	p
P. aegeria	2991	**0.020**	1342	**0.014**	-	-	-	-	-	-	-	-
P. rapae	2790	0.174	1336	**0.018**	6931	0.181	6870	0.781	-	-	-	-
P. tithonus	1294.5	**0.002**	349	0.066	3490	0.065	1725	0.887	3707.5	0.017	1685	0.847

Appendix 3

Within species between-sex differences in vortex score (i.e. flight time). Wilcoxon tests were used, and Bonferroni corrections were applied to account for multiple testing (*p*-values before correction are given in brakets).

Species	n	mean + SE	male	female	W	P-value
P. tithonus	41	43.46 ± 2.88	52.41 ± 3.16	33.09 ± 3.90	360	**< 0.001** (< 0.001)
M. jurtina	33	35.93 ± 3.32	39.38 ± 8.34	34.83 ± 3.57	123.5	1 (0.334)
P. aegeria	114	44.05 ± 2.10	48.63 ± 2.06	29.31 ± 4.99	1628	**0.007** (0.001)
P. rapae	120	50.94 ± 1.35	54.69 ± 1.18	46.65 ± 2.45	2204	0.109 (0.027)
Total	308	45.79 ± 1.10	50.82 ± 1.22	38.61 ± 1.87	15910.5	**< 0.001** (< 0.001)