Assessing Multivariate Constraints to Evolution across Ten Long-Term Avian Studies

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Abstract

Background: In a rapidly changing world, it is of fundamental importance to understand processes constraining or facilitating adaptation through microevolution. As different traits of an organism covary, genetic correlations are expected to affect evolutionary trajectories. However, only limited empirical data are available.

Methodology/Principal Findings: We investigate the extent to which multivariate constraints affect the rate of adaptation, focusing on four morphological traits often shown to harbour large amounts of genetic variance and considered to be subject to limited evolutionary constraints. Our data set includes unique long-term data for seven bird species and a total of 10 populations. We estimate population-specific matrices of genetic correlations and multivariate selection coefficients to predict evolutionary responses to selection. Using Bayesian methods that facilitate the propagation of errors in estimates, we compare (1) the rate of adaptation based on predicted response to selection when including genetic correlations with predictions from models where these genetic correlations were set to zero and (2) the multivariate evolvability in the direction of current selection to the average evolvability in random directions of the phenotypic space. We show that genetic correlations on average decrease the predicted rate of adaptation by 28%. Multivariate evolvability in the direction of current selection was systematically lower than average evolvability in random directions of space. These significant reductions in the rate of adaptation and reduced evolvability were due to a general nonalignment of selection and genetic variance, notably orthogonality of directional selection with the size axis along which most (60%) of the genetic variance is found.

Conclusions: These results suggest that genetic correlations can impose significant constraints on the evolution of avian morphology in wild populations. This could have important impacts on evolutionary dynamics and hence population persistence in the face of rapid environmental change.

Estimation of the additive genetic (co)variance matrix

G

+

G

$$= \mu + \quad + Z \quad + Z \quad + Z \quad + \qquad (1)$$

μ

$a \sim \mathcal{N}(0, \mathrm{G} \otimes \mathrm{A})$ **G**

A

Estimating selection

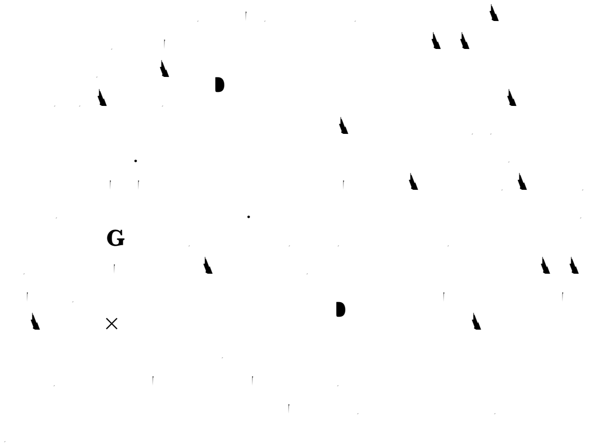
β

γ

$$\beta = \frac{\boldsymbol{\beta}^T \mathbf{G} \boldsymbol{\beta}}{\|\boldsymbol{\beta}\|^2} \tag{4}$$

Table 7. Estimates of directional and non-linear selection gradients for the Red-billed gull, Great reed warbler, and the two Barn swallow populatio[redacted]
intervals.

	Red-billed gull			Great reed warbler			Barn swallow - Badajoz			Barn swallow	
	posterior mode	Low 95%CI	Up 95%CI	posterior mode	Low 95%CI	Up 95%CI	posterior mode	Low 95%CI	Up 95%CI	posterior mo	[redacted]
$\|\| \beta \|\|$	4.22	1.94	7.24	5.23	2.53	8.17	0.54	0.22	1.48	1.06	[redacted]
Wing	1.14	−2.75	5.9	−0.09	−3.79	4.12	0.33	−0.72	1.5	−0.54	[redacted]
Tarsus	1.86	−1.12	4.39	4.04	1.45	7.69	0.12	−0.48	0.65	0.7	[redacted]
Mass	−1.15	−2.39	0.32	−1.78	−3.02	−0.51	0.08	−0.27	0.44	−0.17	[redacted]
Bill	1.86	−1.83	5.35	0.58	−1.48	1.96	0.15	−0.25	0.59	0.32	[redacted]
$Wing^2$	139.96	−27.15	243.35	15.61	−107.1	233.37	−13.47	−35.27	7.07	41.28	[redacted]
$Tarsus^2$	29.1	−33.29	88.21	24.88	−61.64	128.76	2.78	−5.35	9.58	1	[redacted]
$Mass^2$	9.26	17.95	1.23−35(35)-7					−35(35)-7			[redacted]



Natural selection on morphology

Discussion