

Electronic Supplementary Materials

Urban *versus* forest ecotypes are not explained by divergent reproductive selection

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Appendix S1: Details on the field sites and monitoring protocol

Monitoring of great tit populations took place in the city of Montpellier, France (43°36'N, 3°52'E) and in the forest of la Rouvière near Montarnaud, France (43°40'N, 3°40'E). Montpellier is the seventh most populated city in France with a total of 277 639 inhabitants in 2015 and a density of 4 881 inhabitants per square kilometre. Its urban area spreads over 57 square kilometres with 11 square kilometres of green spaces. In autumn 2010, 283 nest-boxes were placed across the city, but at the beginning of the breeding season in 2011, 74 of them had already been stolen or vandalised. Since then, depending on our replacement effort and number of thefts, the number of nest-boxes fluctuated between 203 and 223 among years. Nest-boxes with 32 mm entrance holes were nailed at 2m height or higher, on a variety of trees such as: holm and downy oaks (*Quercus ilex* and *Q. pubescens*), platanus (*Platanus × acerifolia*), European nettle tree (*Celtis australis*), black locust (*Robinia pseudoacacia*), pines (*Pinus halepensis*, *P. pinaster* and *P. pinea*) and olive trees (*Olea europea*).

The forest of La Rouvière is a historical study site where blue tit and great tit populations have been monitored since 1991, with between 51 and 92 great tit nest-boxes placed in cages hanged on top of posts to avoid nest predation. On both sites, great tit nest-boxes were spaced by 100m to avoid intraspecific competition.

Great tits are known to explore an area of 50m radius around their nest-box (Naef-Daenzer 2000). Hence, proportions of green cover were measured for each nest-box in a circle of 100m diameter around the nest-box, giving a measure of habitat artificialisation level. Measures of green cover (*versus* impervious surfaces) around each nest-box were obtained by analysing satellite pictures with QGIS (2018). In the forest, Great tit territories were on average covered at 98.9±2.3% (mean±SD) by vegetation whereas this proportion dropped to 61.9±26.9% in the city, the remaining 38.1% being artificial surfaces (roads, sidewalks, buildings).

Each week, all nest-boxes were visited to follow nest and brood development, providing information on laying date, clutch size, incubation period, number of hatchlings, age of chicks and number of fledglings. Parents were captured inside nest-boxes with mechanical traps when chicks were at least 9 days old, measured for morphological and behavioural traits and ringed with unique metal rings provided by the CRBPO (Museum National d'Histoire Naturelle, Paris). In particular, we measured body mass to the nearest 0.1g with a Pesola spring scale, tarsus length to the nearest 0.01mm with a digital calliper, and wing length and tail length to the nearest 0.5mm with rulers. All these morphological measures, apart from tail length which is rarely measured, have been shown highly repeatable and heritable (Gosler & Harper 2000 & Postma 2014).

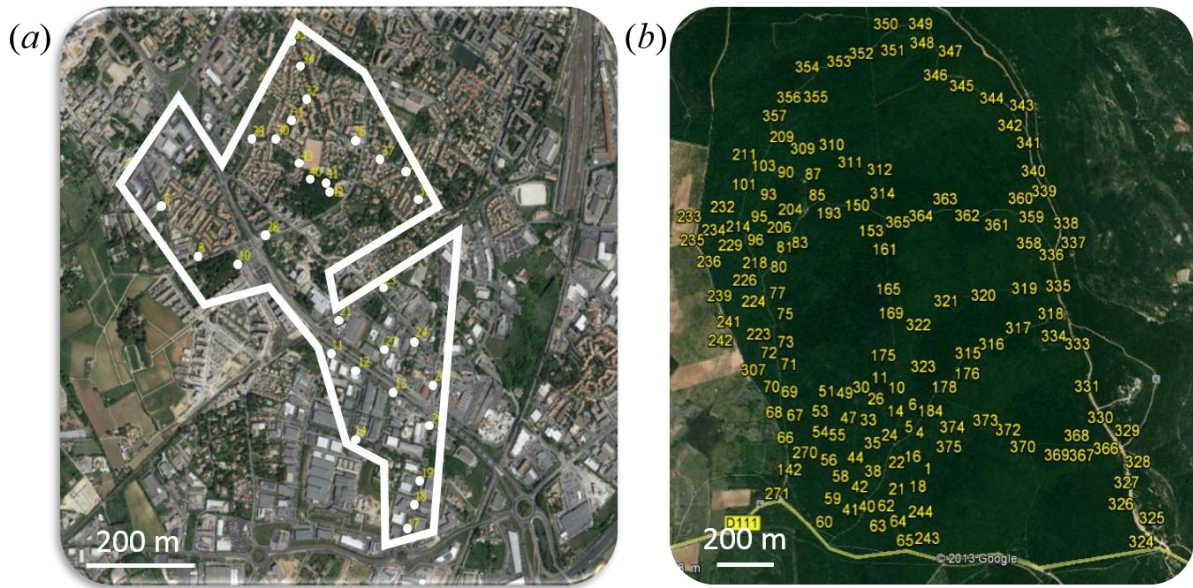


Figure S1: Satellite images of the study sites. (a) One section of the urban city site of Montpellier, France. Each dot represents a nest-box. (b) The forest site, in the forest of La Rouvière, Montarnaud, France. Each number represents a nest-box. Note that for the forest site, numerous nest-boxes are designed for blue tits (entrance whole of 28 mm). © Google Earth.



Figure S2: Variation in great tit body mass across years and between habitats (green = forest, purple = urban). Boxplots of predicted data from the best linear mixed model, representing minimum, 1st quartile, median, 3rd quartile and maximum.



Figure S3: Variation in great tit wing length across years and between habitats (green = forest, purple = urban). Boxplots of predicted data from the best linear mixed model, representing minimum, 1st quartile, median, 3rd quartile and maximum.



Figure S4: Variation in great tit tail length across years and between habitats (green = forest, purple = urban). Boxplots of predicted data from the best linear mixed model, representing minimum, 1st quartile, median, 3rd quartile and maximum.

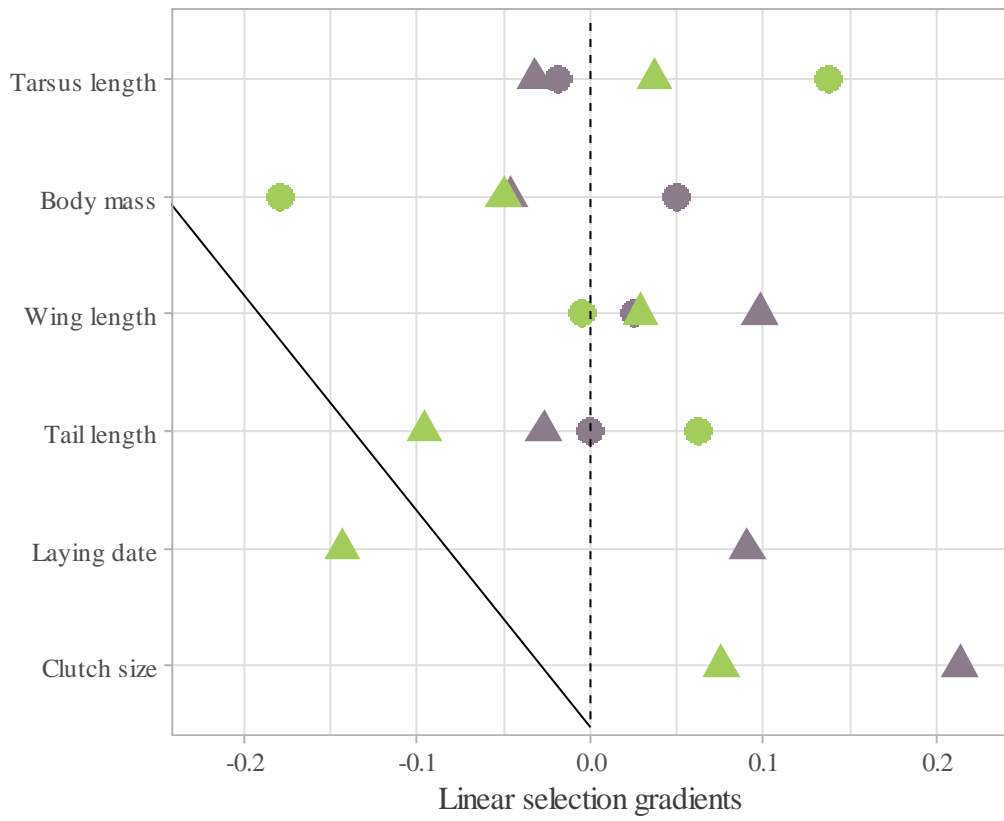


Figure S5: Distribution of linear selection gradients. Green symbols represent selection in the forest habitat and purple symbols selection in the urban habitat. Triangles represent females, circles males.

Table S1: Pearson correlation coefficients between morphological traits and between laying date and clutch size (R function cor.test). Number of observations for morphological traits $N_{\text{forest}}=245$ and $N_{\text{city}}=517$ and for life-history traits $N_{\text{forest}}=192$ and $N_{\text{city}}=543$.

trait 1	trait 2	forest		city	
		correlation	<i>P</i>	correlation	<i>P</i>
tarsus length	body mass	0.387	5.84.E-10	0.531	<2.20.E-16
tarsus length	wing length	0.33	1.30.E-7	0.467	<2.20.E-16
tarsus length	tail length	0.296	1.61.E-5	0.371	<2.20.E-16
body mass	wing length	0.345	8.33.E-14	0.533	<2.20.E-16
body mass	tail length	0.238	6.25.E-4	0.469	<2.20.E-16
wing length	tail length	0.662	2.20.E-16	0.715	<2.20.E-16
laying date	clutch size	-0.085	0.25	-0.114	0.009

Table S2: Output of complete initial linear models (LMER) for morphological traits before removing non-significant variables. Abbreviations: fem = female, hbt = habitat, yrl = yearling, nb indiv. = number of individuals, nb obs. = number of observers.

fixed effects	tarsus length				body condition				wing length				tail length			
	est.	SE	<i>t</i>	<i>P</i>	est.	SE	<i>t</i>	<i>P</i>	est.	SE	<i>t</i>	<i>P</i>	est.	SE	<i>t</i>	<i>P</i>
intercept	19.95	0.10	195.38	<2.E-16	4.15	1.31	3.17	1.6.E-3	60.60	2.82	21.50	<2.E-16	56.15	4.24	13.24	<2.E-16
habitat-urban	-0.18	0.12	-1.54	0.13	-0.12	0.20	-0.58	0.56	-0.34	0.51	-0.67	0.50	-0.43	0.74	-0.58	0.56
year-2014	0.06	0.08	0.72	0.48	-0.81	0.20	-4.01	7.E-05	-0.95	0.55	-1.72	0.09	-0.03	0.74	-0.04	0.97
year-2015	0.01	0.09	0.17	0.87	-1.21	0.22	-5.58	4.E-08	0.42	0.58	0.72	0.47	1.71	0.78	2.20	0.03
year-2016	-0.04	0.10	-0.39	0.70	-0.88	0.22	-3.97	8.E-05	-0.57	0.56	-1.01	0.31	1.42	0.79	1.80	0.07
year-2017	0.19	0.13	1.48	0.14	-0.33	0.23	-1.45	0.147	0.29	0.54	0.54	0.59	1.02	0.80	1.28	0.20
sex-fem	-0.56	0.12	-4.59	6.E-06	-0.57	0.21	-2.73	0.01	-2.73	0.46	-5.94	6.E-09	-3.62	0.72	-5.06	6.E-07
age-yearling	0.04	0.06	0.61	0.54	-0.30	0.15	-2.03	0.04	-1.51	0.34	-4.46	1.E-5	-2.13	0.50	-4.28	0.00
tarsus length	-	-	-	-	0.66	0.06	10.34	<2.E-16	0.83	0.14	6.02	3.9.E-9	0.45	0.21	2.15	0.03
hbt-urb×age-yrl	-0.05	0.07	-0.65	0.51	-0.14	0.15	-0.92	0.36	-0.66	0.36	-1.86	0.06	-0.04	0.51	-0.09	0.93
hbt-urb×sex-fem	-0.12	0.18	-0.70	0.48	-0.13	0.16	-0.83	0.41	-0.04	0.33	-0.11	0.91	0.29	0.52	0.55	0.58
sex-fem×age-yrl	-0.09	0.06	-1.47	0.14	0.15	0.14	1.09	0.28	0.84	0.31	2.70	0.01	0.65	0.44	1.47	0.14
year-14×sex-Fem	0.03	0.08	0.42	0.68	0.38	0.21	1.86	0.06	-0.02	0.50	-0.04	0.97	0.13	0.70	0.19	0.85
year-15×sex-Fem	0.09	0.09	1.01	0.31	0.35	0.21	1.69	0.09	0.76	0.50	1.53	0.13	-0.30	0.70	-0.43	0.67
year-16×sex-Fem	0.19	0.09	2.07	0.04	0.22	0.20	1.11	0.27	-0.05	0.47	-0.10	0.92	0.17	0.67	0.25	0.81
year-17×sex-Fem	0.04	0.10	0.37	0.71	0.23	0.21	1.11	0.27	-0.22	0.48	-0.46	0.65	-0.01	0.69	-0.02	0.98
hbt-urb×year-14	0.03	0.09	0.38	0.70	-0.14	0.22	-0.65	0.51	0.24	0.58	0.42	0.67	-0.33	0.78	-0.42	0.68
hbt-urb×year-15	-0.13	0.10	-1.34	0.18	0.34	0.23	1.45	0.15	-1.32	0.61	-2.16	0.03	-1.36	0.83	-1.65	0.10
hbt-urb×year-16	-0.08	0.11	-0.77	0.44	0.05	0.23	0.21	0.84	0.36	0.57	0.63	0.53	-0.55	0.82	-0.68	0.50
hbt-urb×year-17	-0.28	0.13	-2.09	0.04	-0.20	0.24	-0.85	0.39	-0.28	0.58	-0.48	0.63	-0.46	0.83	-0.56	0.58
hour	-	-	-	-	9.E-4	3.E-4	3.14	1.8.E-3	-	-	-	-	-	-	-	-
random effects	variance	sample size			variance	sample size			variance	sample size			variance	sample size		
individual ring ID	0.28	nb indiv. = 449			3.E-01	nb indiv. = 446			0.14	nb indiv. = 449			2.71	nb indiv. = 441		
observer	0.00	nb obs. = 13			4.E-46	nb obs. = 13			0.15	nb obs. = 13			0.00	nb obs.= 12		
residuals	0.02	N = 554			3.E-01	N = 550			2.78	N =553			3.39	N = 537		

Table S3: Comparing the morphological traits tarsus length, relative body mass, relative wing length and relative tail length between forest and urban great tits using linear mixed models with individual identity and observer identity as random effects. Tarsus, wing and tail lengths are expressed in millimeters and body condition in grams. Abbreviations: fem = female, hbt = habitat, yrl = yearling, nb indiv. = number of individuals, nb obs. = number of observers.

	tarsus length				body mass				wing length				tail length			
mean ± SD	forest		city		forest		city		forest		city		forest		city	
females	19.54 ± 0.51		19.23 ± 0.53		16.61 ± 0.88		16.20 ± 0.89		73.39 ± 1.80		72.58 ± 1.70		61.24 ± 2.55		60.87 ± 2.43	
males	20.01 ± 0.51		19.76 ± 0.57		17.25 ± 0.94		16.98 ± 0.97		76.43 ± 2.09		75.59 ± 2.29		65.35 ± 2.84		64.37 ± 2.93	
fixed effects	est.	SE	t	P	est.	SE	t	P	est.	SE	t	P	est.	SE	t	P
intercept	19.99	0.06	357.70	<2E-16	4.03	1.29	3.12	2.E-03	60.12	2.81	21.37	<2e-16	56.77	4.15	13.69	<2e-16
habitat-urban	-0.27	0.06	-4.73	3.E-06	-0.13	0.10	-1.26	0.21	-0.64	0.48	-1.34	0.18	-0.91	0.26	-3.50	6.E-04
year-2014	ns	ns	ns	ns	-0.69	0.10	-6.69	7.E-11	-0.87	0.50	-1.76	0.08	-0.24	0.35	-0.69	0.50
year-2015	ns	ns	ns	ns	-0.78	0.10	-7.49	3.E-13	0.64	0.53	1.22	0.23	0.59	0.35	1.67	0.10
year-2016	ns	ns	ns	ns	-0.71	0.10	-7.08	5.E-12	-0.71	0.51	-1.39	0.17	1.05	0.34	3.12	3.E-03
year-2017	ns	ns	ns	ns	-0.37	0.10	-3.55	4.E-04	0.28	0.49	0.58	0.57	0.66	0.35	1.90	0.07
sex-fem	-0.49	0.05	-9.73	<2E-16	-0.37	0.08	-4.67	4.E-06	-2.60	0.20	-12.88	<2E-16	-3.15	0.25	-12.59	<2e-16
age-yearling	ns	ns	ns	ns	-0.08	0.12	-0.71	0.48	-1.94	0.23	-8.53	<2E-16	-1.87	0.22	-8.58	<2e-16
tarsus length	ns	ns	ns	ns	0.66	0.06	10.39	<2E-16	0.87	0.14	6.26	1.E-09	0.43	0.21	2.09	0.04
hbt-urb×year-14	ns	ns	ns	ns	-0.16	0.22	-0.73	0.47	0.14	0.58	0.25	0.81	ns	ns	ns	ns
hbt-urb×year-15	ns	ns	ns	ns	0.38	0.23	1.68	0.09	-1.13	0.61	-1.85	0.07	ns	ns	ns	ns
hbt-urb×year-16	ns	ns	ns	ns	0.86	0.23	3.86	0.05	0.47	0.57	0.81	0.42	ns	ns	ns	ns
hbt-urb×year-17	ns	ns	ns	ns	0.19	0.24	0.82	0.42	-0.35	0.58	-0.59	0.55	ns	ns	ns	ns
hbt-urb×age-yrl	ns	ns	ns	ns	-0.28	0.14	-1.99	0.05	ns	ns	ns	ns	ns	ns	ns	ns
sex-fem×age-yrl	ns	ns	ns	ns	ns	ns	ns	ns	0.77	0.31	2.51	0.01	ns	ns	ns	ns
hour	-	-	-	-	8.E-04	0.00	2.91	4.E-03	-	-	-	-	-	-	-	-
random effects	variance		sample size		variance		sample size		variance		sample size		variance		sample size	
individual ring ID	0.28		nb indiv. = 449		0.30		nb indiv. = 446		0.26		nb indiv. = 449		2.87		nb indiv. = 441	
observer	0.00		nb obs. = 13		0.01		nb obs. = 13		0.18		nb obs. = 13		0.01		nb obs.= 12	
residuals	0.02		N = 554		0.30		N = 550		2.67		N =553		3.22		N = 537	

Table S4: Output of complete initial linear models (LMER) on life-history traits before removing non-significant variables. Abbreviations: hbt-urb = urban habitat (contrasted with forest habitat), nb female ID = number of females.

fixed effects	laying date				clutch size			
	est.	SE	<i>t</i>	<i>P</i>	est.	SE	<i>t</i>	<i>P</i>
intercept	99.00	1.73	57.19	<2.E-16	11.20	0.90	12.41	<2.E-16
habitat-urban	-4.05	1.89	-2.15	0.032	-1.60	0.42	-3.85	1.E-04
year-2012	7.96	2.29	3.48	5.E-04	-0.59	0.51	-1.15	0.25
year-2013	10.05	2.32	4.33	1.69E-05	0.64	0.53	1.20	0.23
year-2014	-4.06	2.08	-1.95	5.E-02	-0.07	0.46	-0.15	0.88
year-2015	6.10	2.13	2.87	4.E-03	-0.74	0.48	-1.53	0.13
year-2016	1.45	2.12	0.69	0.49	-0.20	0.47	-0.43	0.67
year-2017	-5.37	2.03	-2.64	8.E-03	-0.46	0.45	-1.03	0.31
hbt-urb×year-12	-2.35	2.53	-0.93	0.35	-0.21	0.56	-0.37	0.71
hbt-urb×year-13	-2.92	2.58	-1.13	0.26	-0.77	0.58	-1.32	0.19
hbt-urb×year-14	1.49	2.35	0.64	0.53	-0.27	0.52	-0.51	0.61
hbt-urb×year-15	-0.40	2.41	-0.17	0.87	0.03	0.54	0.06	0.95
hbt-urb×year-16	2.23	2.38	0.94	0.35	-0.17	0.53	-0.32	0.75
hbt-urb×year-17	3.83	2.27	1.69	0.09	0.09	0.50	0.19	0.85
laying date	-	-	-	-	-0.02	0.01	-2.16	0.03
random effects	variance		sample size		variance		sample size	
female ID	19.39		nb female ID = 662		0.66		nb female ID = 651	
residuals	28.57		N = 724		1.66		N = 713	

Table S5: Comparing laying date and clutch size between forest and urban great tits using linear mixed models with female individual identity as random effect. Abbreviations: hbt-urb = urban habitat (contrasted with forest habitat), nb female ID = number of females.

mean ± SD	laying date				clutch size			
	forest		city		forest		city	
	100.01 ± 7.24 *		97.2 ± 8.35 *		9.16 ± 1.75		7.46 ± 1.51	
fixed effects	est.	SE	t	P	est.	SE	t	P
intercept	99.00	1.73	57.19	<2.E-16	11.23	0.83	13.54	<2.E-16
habitat-urban	-4.05	1.89	-2.15	0.032	-1.75	0.14	-12.61	<2.E-16
year-2012	7.96	2.29	3.48	5.E-04	-0.76	0.22	-3.45	6.E-04
year-2013	10.05	2.32	4.33	2.E-05	0.01	0.23	0.04	0.97
year-2014	-4.06	2.07	-1.95	0.051	-0.27	0.22	-1.26	0.21
year-2015	6.10	2.12	2.87	0.004	-0.74	0.23	-3.25	1.E-03
year-2016	1.45	2.12	0.69	0.493	-0.34	0.22	-1.57	0.12
year-2017	-5.37	2.03	-2.64	0.008	-0.41	0.20	-2.04	4.E-02
hbt-urb×year-12	-2.35	2.53	-0.93	0.354	ns	ns	ns	ns
hbt-urb×year-13	-2.92	2.58	-1.13	0.258	ns	ns	ns	ns
hbt-urb×year-14	1.49	2.35	0.64	0.526	ns	ns	ns	ns
hbt-urb×year-15	-0.40	2.41	-0.17	0.869	ns	ns	ns	ns
hbt-urb×year-16	2.23	2.38	0.94	0.350	ns	ns	ns	ns
hbt-urb×year-17	3.83	2.27	1.69	0.092	ns	ns	ns	ns
laying date	-	-	-	-	-0.02	0.01	-2.05	4.E-02
random effects	variance		sample size		variance		sample size	
female ID	19.38		nb female ID = 662		0.74		nb female ID = 651	
residuals	28.57		N = 724		1.59		N = 713	

* Laying date is expressed in ordinal day, where 1 = January the 1st.

Table S6: Standardised linear and quadratic selection differentials on tarsus length, body condition, wing length and tail length. Values are provided with their standard errors. Bold estimates are significant ($P < 0.05$). “int.” displays the value of the coefficient for interaction between trait and habitat in the merged (forest + city) model.

selection differentials	sex	habitat	tarsus					body mass					wing					tail				
			N	est.	±	SE	int.	N	est.	±	SE	int.	N	est.	±	SE	int.	N	est.	±	SE	int.
linear	female	forest	110	-0.001	±	0.06		109	-0.036	±	0.06		110	-0.007	±	0.06		105	-0.085	±	0.061	
		city	202	-0.022	±	0.043	-0.023	166	-0.022	±	0.044	-0.013	202	0.062	±	0.043	0.019	201	-0.004	±	0.044	0.06
	male	forest	105	0.075	±	0.059		102	-0.086	±	0.06		104	0.003	±	0.06		96	0.042	±	0.061	
		city	195	0.008	±	0.042	-0.073	159	0.05	±	0.042	0.148	195	0.054	±	0.042	0.052	192	0.036	±	0.042	-0.003
quadratic	female	forest	110	0.032	±	0.081		109	-0.067	±	0.071		110	0.109	±	0.066		105	0.107	±	0.074	
		city	202	-0.082	±	0.054	-2.29	166	0.039	±	0.05	0.04	202	-0.016	±	0.054	-0.106	201	0.035	±	0.059	-0.038
	male	forest	105	0.178	±	0.09		102	-0.025	±	0.066		104	0.057	±	0.089		96	-0.04	±	0.93	
		city	195	-0.008	±	0.058	-3.506	159	0.037	±	0.068	0.056	195	-0.031	±	0.065	-0.122	192	-0.031	±	0.06	0.026

Table S7: Standardised quadratic selection gradients on tarsus length, body mass, wing length and tail length. Values are provided with their standard errors. The bold estimate is significant (P=0.036). “Int.” displays the value of the coefficient for interaction between trait and habitat in the merged (forest + city) model.

sex	habitat	sample size	quadratic selection gradients															
			γ_{Tarsus}				$\gamma_{\text{Body mass}}$				γ_{Wing}				γ_{Tail}			
			est.	±	SE	Int.	est.	±	SE	Int.	est.	±	SE	Int.	est.	±	SE	Int.
female	forest	104	-0.018	±	0.130		-0.076	±	0.090		0.002	±	0.136		0.161	±	0.114	
	city	200	-0.166	±	0.076	-0.043	-0.121	±	0.070	0.021	-0.142	±	0.080	-0.017	0.036	±	0.070	-0.011
male	forest	94	0.192	±	0.112		0.042	±	0.096		0.094	±	0.112		0.050	±	0.138	
	city	191	-0.006	±	0.088	-0.095	0.080	±	0.120	0.020	-0.220	±	0.164	-0.048	-0.146	±	0.106	-0.009

Table S8: Comparison of variances between urban and forest habitat for morphological and life history traits. Fisher variance ratio test (*var.test()*, *r* package *stats*). d.f. = degrees of freedom, c.i = 95% confidence interval of f.

	Urban variance	Forest variance	F-test		F	P
			d.f.	c.i.		
tarsus length	0.38	0.32	171	0.65 - 1.08	0.83	0.17
body mass	1.02	0.93	169	0.71 - 1.20	0.91	0.5
wing length	6.3	6.1	170	0.75 - 1.26	0.97	0.811
tail length	10.28	11.44	158	0.86 - 1.46	1.11	0.41
laying date	69.67	52.4	190	0.60 - 0.96	0.75	0.02
clutch size	2.27	3.07	184	1.07 - 1.73	1.35	0.01

Table S9: Standardised linear and quadratic selection differentials on laying date and clutch size. Bold estimates are significant ($P < 0.05$). “Interaction” displays the value of the coefficient for interaction between trait and habitat in the merged (forest + city) model.

selection differentials	habitat	laying date					clutch size				
		N	est.	±	SE	interaction	N	est.	±	SE	interaction
linear	forest	191	-0.163	±	0.056	0.318	185	0.088	±	0.057	0.118
	city	527	0.073	±	0.032		533	0.205	±	0.031	
quadratic	forest	191	-0.017	±	0.087	0.012	185	-0.122	±	0.062	0.102
	city	527	-0.019	±	0.043		533	-0.028	±	0.038	

Table S10: Standardised quadratic selection gradients on laying date and clutch size. Values are provided with their standard errors. The underlined estimate is marginally significant (P=0.054). “Interaction” displays the value of the coefficient for interaction between trait and habitat in the merged (forest + city) model.

habitat	sample size	quadratic selection gradients							
		$\gamma_{\text{Laying date}}$				$\gamma_{\text{Clutch size}}$			
		est.	±	SE	interaction	est.	±	SE	interaction
forest	94	-0.004	±	0.089	-0.006	<u>-0.115</u>	±	<u>0.062</u>	0.100
city	191	4.E-04	±	0.042		-0.028	±	0.038	

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