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Appendix A1

Table A1. Annual number of (no.) breeding long-tailed tits in the Rivelin population, and numbers of adults captured and resighted each year. Number of breeding individuals is likely to be a slight underestimate, since a very small percentage of nests are not found in some years (the exception to this is 2001, when a higher proportion of nests were not found due to reduced field access). Birds were occasionally observed only later in the season when they appeared as helpers, and the total number of adults caught therefore sometimes exceeds the number of breeding adults. Number of adults caught for the first time also includes birds ringed as nestlings and resighted for the first time as adults.

Year	No. breeding adults	Total no. adults caught or sighted	Total no. males caught/sighted	Total no. females caught/sighted	No. adults caught for the first time	No. adults resighted from a previous year
1994	34	44	25	19	44	0
1995	48	46	25	21	27	19
1996	72	70	38	32	44	26
1997	72	70	36	34	35	35
1998	76	68	34	34	35	33
1999	78	74	40	34	47	27
2000	100	100	54	46	57	43
2001	50	42	23	19	24	18

2002	82	80	44	36	63	17
2003	90	93	52	41	65	28
2004	136	143	77	66	83	60
2005	94	99	49	50	39	60
2006	102	103	55	48	47	56
2007	98	94	48	46	62	32
2008	128	139	71	68	87	52
2009	86	84	44	40	38	46
2010	112	115	61	54	65	50
2011	114	112	62	50	64	48
2012	130	120	66	54	59	61

Table A2. Selection of a reference model for adult long-tailed tit survival in the Rivelin population, 1994-2012. Shown is the $\Delta\text{AICc} < 20$ top subset of models from all reduced models nested within the global structural model $\phi(\sim\text{time} \times \text{sex} \times \text{ringingAge})p(\sim\text{sex} \times \text{ringingAge})$. Also shown are the null model (final row) and the ‘reference null’ model $\phi(\sim 1)p(\sim\text{sex})$ used to calculate r^2_{dev} of climatic models (penultimate row). In all models, p was fixed to 0.4 in 2001, to reflect the observed reduction in recapture/resighting probability that year. Note that ringing age showed some influence on survival/recapture probability (birds ringed as nestlings tended to show higher survival); we therefore included ringing age as a main effect in the final subset of climatic survival models, but this did not improve their AICc and we were thus confident that our reference model was suitable.

Model	npar	ΔAICc	AICc weight	Deviance
$\text{Phi}(\sim\text{time})p(\sim\text{sex})$	20	0.0	0.216	451.2
$\text{Phi}(\sim\text{time} + \text{ringingAge})p(\sim\text{sex})$	21	0.8	0.146	449.9
$\text{Phi}(\sim\text{sex} + \text{time})p(\sim\text{sex})$	21	1.6	0.095	450.8
$\text{Phi}(\sim\text{time})p(\sim\text{sex} + \text{ringingAge})$	21	1.8	0.087	451.0
$\text{Phi}(\sim\text{time})p(\sim\text{sex} \times \text{ringingAge})$	22	1.9	0.082	449.0
$\text{Phi}(\sim\text{time} + \text{ringingAge})p(\sim\text{sex} + \text{ringingAge})$	22	2.3	0.070	449.4
$\text{Phi}(\sim\text{time} + \text{ringingAge})p(\sim\text{sex} \times \text{ringingAge})$	23	2.4	0.066	447.4
$\text{Phi}(\sim\text{sex} + \text{ringingAge} + \text{time})p(\sim\text{sex})$	22	2.7	0.057	449.8
$\text{Phi}(\sim\text{sex} + \text{time})p(\sim\text{sex} + \text{ringingAge})$	22	3.4	0.039	450.5
$\text{Phi}(\sim\text{sex} + \text{time})p(\sim\text{sex} \times \text{ringingAge})$	23	3.6	0.035	448.7
$\text{Phi}(\sim\text{sex} + \text{ringingAge} + \text{time})p(\sim\text{sex} + \text{ringingAge})$	23	4.2	0.027	449.2
$\text{Phi}(\sim\text{sex} + \text{ringingAge} + \text{time})p(\sim\text{sex} \times \text{ringingAge})$	24	4.3	0.025	447.3
$\text{Phi}(\sim\text{time})p(\sim 1)$	19	5.7	0.013	458.9
$\text{Phi}(\sim\text{sex} + \text{time})p(\sim 1)$	20	6.0	0.011	457.2
$\text{Phi}(\sim\text{time} + \text{ringingAge})p(\sim 1)$	20	6.1	0.010	457.3
$\text{Phi}(\sim\text{sex} + \text{ringingAge} + \text{time})p(\sim 1)$	21	7.0	0.007	456.2
$\text{Phi}(\sim\text{time})p(\sim\text{ringingAge})$	20	7.7	0.005	458.9
$\text{Phi}(\sim\text{time} + \text{ringingAge})p(\sim\text{ringingAge})$	21	7.9	0.004	457.1
$\text{Phi}(\sim\text{sex} + \text{time})p(\sim\text{ringingAge})$	21	8.0	0.004	457.1
$\text{Phi}(\sim\text{sex} + \text{ringingAge} + \text{time})p(\sim\text{ringingAge})$	22	8.9	0.003	456.0
$\text{Phi}(\sim 1)p(\text{sex})$	3	37.9	<0.001	523.7
$\text{Phi}(\sim 1)p(\sim 1)$	2	43.8	<0.001	531.5

Table A3. Pearson correlation coefficients between weather variables and population size in the Rivelin study site, 1994–2012. Note that only average indices (t1-4 and p1-4) were used in survival analyses. Average indices: t = mean temperature; p = total precipitation. Extreme indices: c = number of cold days (minimum temperature <0°C); g = number of glaze days (minimum temperature <0°C and total precipitation >1mm); h = number of hot days (maximum temperature >25°C); r = number of rain days (total precipitation ≥10mm). Seasons as defined in the text: 1 = spring, 2 = summer, 3 = autumn, 4 = winter. Pop = population size at the end of season 1.

	t1	t2	t3	t4	p1	p2	p3	p4	c1	c3	c4	g1	g4	h2	r1	r2	r3	r4	pop
t1	1	-0.27	0.22	0.15	-0.21	0.41	-0.36	-0.15	-0.69	-0.43	-0.17	-0.42	-0.01	-0.40	-0.04	0.29	-0.20	-0.15	0.3
t2	-0.27	1	0.27	0.08	-0.02	-0.33	-0.28	0.14	0.54	0.06	-0.06	0.46	0.01	0.83	-0.31	-0.36	-0.18	0.11	-0.06
t3	0.22	0.27	1	0.24	-0.10	-0.16	-0.39	0.20	0.19	-0.32	-0.26	0.52	-0.07	0.34	-0.18	-0.04	-0.31	-0.04	0.09
t4	0.15	0.08	0.24	1	0.12	0.08	-0.22	0.46	-0.05	-0.23	-0.92	0.17	-0.81	0.03	0.07	0.11	-0.33	0.40	0.03
p1	-0.21	-0.02	-0.10	0.12	1	0.08	0.57	0.21	0.13	-0.28	-0.09	0.30	0.16	-0.04	0.84	0.15	0.66	0.16	0.28
p2	0.41	-0.33	-0.16	0.08	0.08	1	-0.19	-0.28	-0.47	-0.12	-0.10	-0.35	0.11	-0.52	0.25	0.90	-0.09	-0.26	0.13
p3	-0.36	-0.28	-0.39	-0.22	0.57	-0.19	1	0.04	0.01	0.02	0.28	-0.14	0.14	-0.23	0.47	-0.01	0.92	0.09	0.07
p4	-0.15	0.14	0.20	0.46	0.21	-0.28	0.04	1	0.16	-0.53	-0.25	0.36	-0.40	0.12	0.00	-0.27	-0.08	0.84	-0.34
c1	-0.69	0.54	0.19	-0.05	0.13	-0.47	0.01	0.16	1	0.27	0.12	0.76	-0.05	0.61	-0.08	-0.48	0.02	0.19	-0.03
c3	-0.43	0.06	-0.32	-0.23	-0.28	-0.12	0.02	-0.53	0.27	1	0.08	-0.13	-0.01	0.18	-0.34	-0.14	-0.03	-0.22	-0.06
c4	-0.17	-0.06	-0.26	-0.92	-0.09	-0.10	0.28	-0.25	0.12	0.08	1	-0.12	0.7	0.01	-0.07	-0.11	0.36	-0.14	-0.10
g1	-0.42	0.46	0.52	0.17	0.30	-0.35	-0.14	0.36	0.76	-0.13	-0.12	1	-0.11	0.65	0.15	-0.29	-0.10	0.22	-0.05
g4	-0.01	0.01	-0.07	-0.81	0.16	0.11	0.14	-0.40	-0.05	-0.01	0.70	-0.11	1	-0.04	0.18	0.09	0.35	-0.49	-0.05
h2	-0.40	0.83	0.34	0.03	-0.04	-0.52	-0.23	0.12	0.61	0.18	0.01	0.65	-0.04	1	-0.28	-0.42	-0.18	0.14	-0.21
r1	-0.04	-0.31	-0.18	0.07	0.84	0.25	0.47	0.00	-0.08	-0.34	-0.07	0.15	0.18	-0.28	1	0.31	0.59	-0.07	0.19
r2	0.29	-0.36	-0.04	0.11	0.15	0.90	-0.01	-0.27	-0.48	-0.14	-0.11	-0.29	0.09	-0.42	0.31	1	0.07	-0.29	0.04
r3	-0.20	-0.18	-0.31	-0.33	0.66	-0.09	0.92	-0.08	0.02	-0.03	0.36	-0.10	0.35	-0.18	0.59	0.07	1	-0.02	0.13
r4	-0.15	0.11	-0.04	0.40	0.16	-0.26	0.09	0.84	0.19	-0.22	-0.14	0.22	-0.49	0.14	-0.07	-0.29	-0.02	1	-0.23
pop	0.30	-0.06	0.09	0.03	0.28	0.13	0.07	-0.34	-0.03	-0.06	-0.10	-0.05	-0.05	-0.21	0.19	0.04	0.13	-0.23	1

Table A4. Annual seasonal weather values and population size in the Rivelin study site, 1994-2011.

Columns display seasonal means, where t = mean seasonal temperature (°C), p = total seasonal precipitation (mm), numerals 1-4 = seasons as defined in the text, popSize = population size at the end of season 1. The overall mean and standard deviation (st dev) of each time series are also shown (bottom two rows).

Year	t1	t2	t3	t4	p1	p2	p3	p4	popSize
1994	8.7	16.3	10.4	5.5	199.0	92.7	309.4	361.5	73
1995	8.9	17.2	11.3	2.7	136.6	45.9	158.0	212.5	129
1996	7.4	16.1	10.1	4.0	129.7	155.4	232.0	213.2	139
1997	9.7	16.6	10.5	6.3	127.7	296.2	166.4	173.3	136
1998	9.5	15.2	10.2	5.3	241.9	235.1	296.6	195.3	163
1999	10.1	16.1	11.4	5.3	225.6	166.6	213.2	257.5	226
2000	9.2	15.6	10.3	4.1	258.7	161.2	425.3	237.8	269
2001	8.4	16.2	11.3	5.2	194.4	212.8	205.4	257.9	103
2002	9.8	16.1	10.5	4.3	137.5	248.2	306.2	222.4	177
2003	10.0	17.4	10.5	5.1	126.6	169.9	120.8	239.2	176
2004	9.7	16.5	10.9	5.4	197.4	295.4	159.1	159.1	336
2005	9.1	16.4	11.5	4.4	131.9	179.7	259.8	122.2	148
2006	8.3	17.7	12.5	6.5	234.5	141.3	228.4	318.5	210
2007	10.2	15.4	10.9	5.5	134.1	425.7	109.7	277.6	144
2008	8.9	16.1	10.2	4.0	221.5	248.0	257.6	134.4	242
2009	9.9	16.1	11.3	2.4	190.0	359.4	233.3	166.7	168
2010	8.9	16.1	9.9	3.5	102.8	153.7	250.1	171.9	191
2011	10.5	15.5	12.4	5.4	59.8	108.2	126.8	221.6	216
mean	9.3	16.3	10.9	4.7	169.4	205.3	225.5	219.0	180
st dev	0.8	0.7	0.8	1.1	55.5	95.6	79.9	61.9	63

Table A5. Climatic models of adult long-tailed tit survival in the Rivelin population, 1994–2012.

Shown are the $\Delta AIC < 2_{\text{climatic}}$ top subset of models, which were used to construct the climatic model average. $\Delta AICc_{\text{time}}$ and $\Delta AICc_{\text{climatic}}$ indicate the $\Delta AICc$ of the focal model with respect to the reference model $\phi(\sim \text{time})p(\text{sex})$ and best climatic model $\phi(\sim t1 + p1 + t3 + p3 + t1 : p1)p(\sim \text{sex})$, respectively; r^2 indicates the percentage of temporal deviance explained. In all models, p was modelled separately for each sex, and was fixed to 0.4 in 2001. Notation for survival models follows abbreviations used previously, where t indicates mean seasonal temperature, p total seasonal precipitation, the numerals 1-4 seasons as defined in the text, and : the interaction term.

Survival model	npar	$\Delta AICc_{\text{time}}$	$\Delta AICc_{\text{climatic}}$	r^2
$\Phi(\sim t1+p1+t3+p3+t1:p1)p(\sim \text{sex})$	8	-5.11	0.00	73.3
$\Phi(\sim t1+p1+t3+p3+t1:p1)p(\sim \text{sex})$	8	-4.86	0.25	73.0
$\Phi(\sim t1+p1+t3+t1:p1)p(\sim \text{sex})$	7	-4.85	0.26	70.2
$\Phi(\sim t1+p1+t3+t1:p1+t3:p3+t1^2)p(\sim \text{sex})$	9	-4.67	0.44	75.5
$\Phi(\sim t1+p1+t3+t1:p1+t1^2)p(\sim \text{sex})$	8	-3.94	1.17	71.7
$\Phi(\sim t1+p1+t3+p3+t1:p1+t3:p3)p(\sim \text{sex})$	9	-3.66	1.45	74.1
$\Phi(\sim t1+p1+t3+t1:p1+p1^2)p(\sim \text{sex})$	8	-3.64	1.47	71.3
$\Phi(\sim t1+p1+t3+p3+t1:p1+t1^2)p(\sim \text{sex})$	9	-3.47	1.64	73.8
$\Phi(\sim t1+p1+t3+t1:p1+t1^2+p1^2)p(\sim \text{sex})$	9	-3.21	1.90	73.5
$\Phi(\sim t1+p1+t3+p3+t1:p1+p1^2)p(\sim \text{sex})$	9	-3.18	1.93	73.4
$\Phi(\sim t1+p1+t3+p3+t1:p1+p3^2)p(\sim \text{sex})$	9	-3.13	1.98	73.4

Table A6. Future climate projections for the Weston Park Weather Station, for the period 2070–2099. Data on historical (1994–2011) and projected future (2070–2100) absolute climatic variables were extracted from UKCP09 for the 25 × 25 km grid square including Rivelin Valley, and used to calculate a percentage change factor that was applied to the historic (1994–2011) mean weather variables from the Weston Park weather station. CDF = cumulative distribution function, representing the percentage likelihood that the increase will be less than this projection; temp = mean seasonal temperature (°C); prec = total seasonal precipitation (mm). Equivalent values were also calculated for the periods 2010–2039 and 2040–2069, but are not shown here for the sake of clarity.

Emissions scenario	cdf	Spring temp	Autumn temp	Spring prec	Autumn prec
Historical mean	--	9.3	10.9	169.4	225.5
Low	10%	9.6	11.7	174.3	196.1
	50%	10.7	13.0	189.5	219.3
	90%	12.1	14.4	206.2	245.5
Medium	10%	10.0	12.4	175.5	200.9
	50%	11.4	13.8	189.5	220.8
	90%	13.1	15.6	204.8	242.9
High	10%	10.7	13.0	174.3	198.8
	50%	12.3	14.7	189.2	221.6
	90%	14.4	16.8	205.4	247.4

Figure A1. Lack of relationship between adult long-tailed tit survival estimates (●) from the reference model $\phi(\sim\text{time})p(\text{sex})$ and four weather variables, for the Rivelin population in the years 1994–2012. Only weather variables that do not show a univariate relationship with survival are displayed here, namely (a) mean summer temperature, (b) total summer precipitation, (c) mean winter temperature, (b) total winter precipitation. For relationships between survival and spring/autumn weather, see Fig. 1.

