ELECTRONIC SUPPLEMENTARY MATERIAL

Nepotism and subordinate tenure in a cooperative breeder

Martha J. Nelson-Flower, Amanda R. Ridley

METHODS

Forty-five wild groups of southern pied babblers were habituated to an observer 2 – 3 m away. Habituated groups were visited at least twice per week for four-hour observation sessions in the mornings and two-hour observation sessions in the evenings. Adults (at least one year old) could be discerned by their plumage [1]. Dominance status within groups was determined using behavioural cues and, for females, vocalizations during inter-group conflicts [2]. Microsatellite genotyping was used with life-history data to construct a pedigree [3]. The majority of young (95.2%) were the offspring of the dominant pair and extra-group parentage was never observed [3]. There was no sex-bias in the age or distance of dispersal, or in the resulting population fine-scale genetic structure [4,5].

We originally had 478 subordinate tenures of 459 subordinates living in 41 groups. We excluded subordinates if their tenure was ongoing at the end of the observation period (n = 53) or if their tenure finished because they had likely died (vanished having never been observed prospecting or corpse found, n = 247). To understand the effects of subordinate tenure length on the likelihood of acquiring dominance, we asked whether the subordinate acquired dominance or not in the immediate period (within 90 days) after its subordinate tenure ended. We included only those individuals for which definite assignment of dominance status was possible, resulting in a dataset of 103 subordinate tenures of 90 birds from 31 groups (Data table 1 in ESM2).

To investigate subordinate tenure length, we classified subordinates based on their relationship to the dominant pair at the end of their tenure: living with two related dominants (almost always parents), a related same-sex dominant but unrelated opposite-sex dominant, an unrelated same-sex dominant but related opposite-sex dominant, or two unrelated dominants. We first used GLMMs to investigate the subordinate tenure length of subordinates living with one related and one unrelated dominant (n = 85), after excluding subordinates with ongoing tenures or those that had likely died. We calculated subordinate tenure as the number of days that an individual remained subordinate after starting to live with the unrelated dominant. We restricted each subordinate to appear in the dataset only once, removing extra (later) tenures that fit the above criteria (n = 4), leaving 81 subordinate tenures in the dataset (Data table 2 in ESM2). This dataset included subordinates that left natal groups to join close relatives (full siblings or parents) in non-natal groups (n = 14); there was no sex bias in leaving the natal group (n = 6 females, 8 males) or in following a same- versus opposite-sex relative (Nelson-Flower & Ridley, in prep). There was no difference in the age at which subordinate males and females began living with unrelated dominant males or females.

Finally, we compared tenure length of subordinates living with various combinations of related or unrelated dominants (both related, opposite-sex unrelated, same-sex unrelated, both unrelated). We again calculated subordinate tenure as the number of days that an individual remained subordinate after starting to live with an unrelated dominant. For those subordinates living with two unrelated dominants we used the day the second unrelated dominant arrived in the group as the starting point. We also wanted to include in this comparison those individuals that finished their subordinate tenures while still living with both parents. Mean age of subordinates at the start of tenure with an unrelated dominant was 443.6 ± 25.2 days. Therefore, for subordinates that lived with parents for their entire tenure, we subtracted 444 days from the time they stayed as subordinates (if these subordinates stayed less than 444 days as subordinates they were excluded from the analysis: n = 28). We also excluded second or later tenures of subordinates in order to avoid pseudoreplication (n = 16). Overall we examined 134 subordinate tenures (Data table 3 in ESM2). We used Wilcoxon rank sum tests to compare tenure between the different classes of subordinate and used Bonferroni's correction for multiple comparisons. We examined males and females separately. We did not correct for the subordinate's age in this analysis, though the previous analysis using GLMMs did include subordinate age.

Statistical analysis was performed within R v. 3.2.2 [6] using R packages 'lme4' v. 1.1-10 [7] and 'glmmADMB' v. 0.8.0 [8] for Generalized Linear Mixed Models. We assessed model fit using Akaike's information criterion adjusted for small sample sizes (AICc; [9]). We first specified a global model including all terms of interest; submodels were then derived from this [10]. When one or more submodels scored within two AICc units of the best submodel, we employed model averaging using 'MuMIn' v.1.15.1 [11]. Continuous variables were centred and scaled [10]. Non-natal subordinates are uncommon in large groups (M.J. Nelson-Flower, unpublished data); therefore, natal group presence and group size were not included in any models together.

RESULTS

Intercept	Sex	Tenure length	Sex * tenure length	Degrees of freedom	Log likelihood	AICc	delta	weight
1.049	**+**	**0.968**	**+**	**6**	**-52.650**	**118.2**	**0**	**0.830**
1.191	+	2.288		5	-55.750	122.1	3.94	0.115
0.833		2.336		4	-57.596	123.6	5.43	0.055
0.916	+			4	-65.815	140.0	21.86	0
				3	-67.202	140.6	22.47	0

Parameter	Estimate	Standard Error	Confidence Interval	*P*-value
Intercept	**1.0492**	**0.3753**	**0.397, 2.007**	**0.005**
Tenure length	0.9684	0.7738	-0.513, 2.632	0.211
Sex (male)	-0.5499	0.5401	-1.607, 0.568	0.309
Tenure length * sex (male)	**3.2498**	**1.4596**	**0.648, 6.586**	**0.026**

Table S1 Results of GLMM models with binomial error distributions and logit-link functions investigating acquisition of dominance and how it is affected by subordinate sex interacted with subordinate tenure length. The full set of models is shown (top), and the significant terms from the minimal model (> Δ AICc 2; bottom). Dataset includes 103 tenures of 90 subordinates in 31 groups.

Intercept	Age at start	Unrelated dominant	Sex	Sex * unrelated dominant	Natal group	Age at start * sex	Group size	Sex * group size	Sex * natal group	Degrees of freedom	Log likelihood	AICc	delta	weight
5.810	**-0.827**	**+**	**+**	**+**						**7**	**-541.954**	**1099.4**	**0**	**0.244**
5.601	**-0.755**	**+**	**+**	**+**	**+**					**8**	**-541.577**	**1101.2**	**1.71**	**0.104**
5.810	-0.809	+	+	+		+				8	-541.949	1101.9	2.46	0.071
5.754	-0.875	+	+	+			+			9	-540.826	1102.2	2.74	0.062
5.454	-0.748	+			+					6	-544.728	1102.6	3.15	0.050
5.732	-0.837									4	-547.058	1102.6	3.20	0.049
5.869	-0.871	+								5	-545.962	1102.7	3.28	0.047
5.990	-0.844	+	+	+			+	+		11	-538.646	1103.1	3.68	0.039
5.378	-0.727				+					5	-546.255	1103.3	3.87	0.035
5.678	-0.744	+	+		+					7	-543.945	1103.4	3.98	0.033

Intercept	Age at start	Unrelated dominant	Sex	Sex * unrelated dominant	Natal group	Age at start * sex	Group size	Sex * group size	Sex * natal group	Degrees of freedom	Log likelihood	AICc	delta	weight
6.096	-0.851	+	+							6	-545.198	1103.5	4.09	0.032
5.592	-0.712	+	+	+	+	+				9	-541.549	1103.6	4.19	0.030
5.603	-0.756	+	+	+	+				+	9	-541.577	1103.7	4.25	0.029
5.754	-0.871	+	+	+		+	+			10	-540.826	1104.8	5.35	0.017
5.743	-0.835		+							5	-547.05	1104.9	5.46	0.016
5.892	-0.884	+					+			7	-544.857	1105.2	5.81	0.013
5.385	-0.727		+		+					6	-546.253	1105.6	6.20	0.011
6.002	-0.772	+	+	+		+	+	+		12	-538.559	1105.7	6.26	0.011
5.688	-0.850						+			6	-546.327	1105.8	6.35	0.010
5.665	-0.684	+	+		+	+				8	-543.898	1105.8	6.35	0.010
6.127	-0.867	+	+				+			8	-543.917	1105.8	6.39	0.010
5.647	-0.737	+	+		+				+	8	-543.938	1105.9	6.43	0.010
6.096	-0.836	+	+			+				7	-545.195	1105.9	6.48	0.010
5.566	-0.700	+	+	+	+	+			+	10	-541.545	1106.2	6.79	0.008
5.745	-0.810		+			+				6	-547.040	1107.2	7.77	0.005
5.588	-0.776		+		+				+	7	-546.034	1107.6	8.16	0.004
5.434		+	+	+	+					7	-546.035	1107.6	8.16	0.004
5.364	-0.647		+		+	+				7	-546.164	1107.9	8.42	0.004
6.381	-0.844	+	+				+	+		10	-542.469	1108.1	8.64	0.003
5.696	-0.848		+				+			7	-546.321	1108.2	8.73	0.003
5.603	-0.659	+	+		+	+			+	9	-543.875	1108.3	8.84	0.003
6.127	-0.868	+	+			+	+			9	-543.916	1108.4	8.92	0.003
5.931		+	+	+						6	-547.636	1108.4	8.96	0.003
5.263		+			+					5	-548.824	1108.4	9.01	0.003
5.180					+					4	-550.034	1108.6	9.15	0.003
5.545		+	+		+					6	-547.990	1109.1	9.67	0.002
5.254		+	+	+	+				+	8	-545.815	1109.6	10.19	0.001
5.553	-0.727		+		+	+			+	8	-546.011	1110.0	10.58	0.001

Intercept	Age at start	Unrelated dominant	Sex	Sex * unrelated dominant	Natal group	Age at start * sex	Group size	Sex * group size	Sex * natal group	Degrees of freedom	Log likelihood	AICc	delta	weight
5.698	-0.835		+			+	+			8	-546.318	1110.6	11.19	0.001
6.390	-0.791	+	+			+	+	+		11	-542.435	1110.7	11.25	0.001
5.206			+		+					5	-550.017	1110.8	11.39	0.001
										3	-552.379	1111.1	11.63	0.001
5.382		+	+		+				+	7	-547.804	1111.1	11.70	0.001
5.841	-0.821		+				+	+		9	-545.355	1111.2	11.80	0.001
5.988		+	+	+			+			8	-546.863	1111.7	12.28	0.001
6.223		+	+							5	-550.491	1111.8	12.34	0.001
5.925		+								4	-551.656	1111.8	12.40	0
6.228		+	+	+			+	+		10	-544.611	1112.4	12.92	0
5.856			+							4	-552.254	1113.0	13.59	0
5.183			+		+				+	6	-550.014	1113.2	13.72	0
5.855	-0.763		+			+	+	+		10	-545.303	1113.7	14.31	0
5.876							+			5	-551.613	1114.0	14.58	0
6.317		+	+				+			7	-549.270	1114.1	14.63	0
6.051		+					+			6	-550.539	1114.2	14.77	0
6.581		+	+				+	+		9	-547.714	1116.0	16.52	0

Parameter	Estimate	Standard Error	Confidence Interval	*P*-value
Intercept	**5.748**	**0.279**	**5.194, 6.302**	**< 0.001**
Age at start	**-0.806**	**0.228**	**-1.259, -0.353**	**< 0.001**
Unrelated dominant (same)	-0.129	0.295	-0.716, 0.458	0.667
Sex (male)	0.088	0.303	-0.516, 0.692	0.776
Unrelated dominant (same) * Sex (male)	**-1.391**	**0.530**	**-2.446, -0.335**	**0.010**
Natal group (natal)	0.086	0.221	-0.360, 0.937	0.383

Table S2 Results of GLMM models with negative binomial error distributions and logit-link functions investigating subordinate tenure (days) and how it is affected by subordinate sex interacted with: the presence of an unrelated dominant of the same or opposite sex, subordinate age in days at the start of the period of interest, the presence of the natal group, and size of the group. The size of the group and whether the tenure occurred in a natal group or not were highly correlated and therefore were not included in the same models. The full set of models is shown (top), and the significant terms from the minimal model (within Δ AICc 2; bottom). Dataset includes 81 subordinate tenures in 27 groups.

REFERENCES

1. Ridley, A. R. & Raihani, N. J. 2007 Variable postfledging care in a cooperative bird : causes and consequences. *Behav. Ecol.* **18**, 994–1000. (doi:10.1093/beheco/arm074)
2. Golabek, K. A. & Radford, A. N. 2013 Chorus-call classification in the southern pied babbler: multiple call types given in overlapping contexts. *Behaviour* **150**, 691–712. (doi:10.1163/1568539X-00003074)
3. Nelson-Flower, M. J., Hockey, P. A. R., O'Ryan, C., Raihani, N. J., du Plessis, M. A. & Ridley, A. R. 2011 Monogamous dominant pairs monopolize reproduction in the cooperatively breeding pied babbler. *Behav. Ecol.* **22**, 559–565. (doi:10.1093/beheco/arr018)
4. Raihani, N. J., Nelson-Flower, M. J., Golabek, K. A. & Ridley, A. R. 2010 Routes to breeding in cooperatively breeding pied babblers Turdoides bicolor. *J. Avian Biol.* **41**, 681–686. (doi:10.1111/j.1600-048X.2010.05211.x)
5. Nelson-Flower, M. J., Hockey, P. A. R., O'Ryan, C. & Ridley, A. R. 2012 Inbreeding avoidance mechanisms: dispersal dynamics in cooperatively breeding southern pied babblers. *J. Anim. Ecol.* **81**, 876–883. (doi:10.1111/j.1365-2656.2012.01983.x)
6. R Core Team 2015 R: A language and environment for statistical computing.
7. Bates, D., Maechler, M., Bolker, B. M. & Walker, S. 2015 Fitting linear mixed-effects models using lme4. *J. Stat. Softw.* **67**, 1–48. (doi:10.18637/jss.v067.i01)
8. Skaug, H., Fournier, D., Bolker, B., Magnusson, A. & Nielsen, A. 2014 Generalized Linear Mixed Models using AD Model Builder.
9. Burnham, K. P. & Anderson, D. R. 2002 *Model selection and multimodel inference*. 2nd ed. New York, USA: Springer.
10. Grueber, C. E., Nakagawa, S., Laws, R. J. & Jamieson, I. G. 2011 Multimodel inference in ecology and evolution : challenges and solutions. *J. Evol. Biol.* **24**, 699–711. (doi:10.1111/j.1420-9101.2010.02210.x)
11. Barton, K. 2015 MuMIn: Multi-model inference.