Animal Biology

Association of social group with both life-history traits and brain size in cooperatively breeding birds

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Supplementary material

Table S1.

Species, average group size, *maximum group size*, *average helper number*, *maximum helper number*, brain size (mm^3), body mass (g), clutch size, egg size, developmental time (days), and longevity (years).

Species	Average group size	Reference	Maximum group size	Reference	Average helper number	Reference	Max helper number	Reference	Brain size	Reference	Body size	Reference	Clutch size	Reference	Egg size	Reference	Developmental Time	Reference	Longevity	Reference
Acanthisitta chloris	3	51	8	51							6.5	27	4	57	1.34	57			6	33
Acanthiza chrysorrhoa	5	51	30	51					0.43	27	9.4	27	3.5	57			34.9	27	13.1	33
Acanthiza lineata	4	51	27	51					0.51	27	6.7	27	3	57	1.32	57	34.8	27	23.51	33
Acanthiza reguloides	6	51	30	51					0.39	27	7.5	27	3.5	57	1.22	57	28.4	27	9.526	33
Acrocephalus baeticatus	2.1	5			1	24							2.7	57	1.59	57				
Acrocephalus melanopogon	1	5											4	57	1.6	57				

Acrocephalus sechellensis	2.9	38			0.58	35		0.45	27	10.8	27	5	57	1.65	57	27.5	27		
Aegithalos caudatus	3	38			1.92	37						10	57	0.88	57			11.08	33
Aegithalos concinnus	3	51	3	51	1	51		0.37	27	6.1	27	6.5	57			29.25	27		
Alophoixus pallidus	2	5						1.24	27	47	27	3	57			23.5	27		
Amaurornis flavirostra	2	5						1.47	27	89.5	27	3	57	9.7	57	18	27	3.91	33
Ammodramus savannarum	3	51	3	51				0.65	27	17.45	27	4.28	57	2.01	57	20.5	27		
Amytornis housei	6	51	6	51						29	51	2	57						
Amytornis woodwardi	4	51	4	51						34.5	51								
Anthochaera carunculata	3	51	150	51				2.2	27	106.4	27	2	57	7.69	57	36	27		
Anthochaera chrysoptera	3	51	75	51				1.7	27	68.35	27	2	57	5.52	57	28.5	27		
Aphelocephala leucopsis	6	5						0.54	27	12.35	27	3.5	57	2	57			14.33	33
Aphelocoma californica	4	51	4	51				0.47	27	10.4	27	2.5	57	1.52	57				

Aphelocoma coerulescens	8	51	8	51	1.8	63	6	68	2.85	27	77.15	27	3.27	63	5.8	57	35.4	27	15.8	33
Aphelocoma ultramarina	25	51	25	51					3.61	27	131	27	4.14	57	7.9	57	43.5	27	19	33
Apteryx australis	3	51	3	51							2250	51	2	57	443	57			35	33
Artamus cinereus	10	51	30	51					0.92	27	35.6	27			3.23	57	30.5	27		
Artamus cyanopterus	3	51	25	51	1	80			1	27	35.5	27	3	80	3.3	57	32.7	27	8.19	33
Artamus leucorynchus	7	51	20	51					1.08	27	41.7	27					32.5	27		
Artamus minor	4	51	15	51					0.52	27	15	27			1.93	57	34	27		
Baeolophus bicolor	3.1	5							1.01	27	21.6	27	5.5	57	1.9	57	29.5	27	13.3	33
Baeolophus wollweberi	4.3	5																	6.6	33
Batis capensis	2	5							0.68	27	11.6	27	2.1	57	1.75	57	35	27	10.08	33
Bradornis pallidus					1	34									2.01	57			4.16	33
Bucorvus cafer	3.5	5			2	34									100.5	57			70	33
Calcarius pictus					1.53	10	3	10					3.94	57	2.55	57				
Calocitta formosa	6	51	6	51	3.5	48	9	48			209	51								

Campylorhynchus brunneicapillus	2	5							1.34	27	38.9	27	3.18	57	3.48	57	37.5	27		
Campylorhynchus griseus	2.6	38							1.31	27	42.4	27								
Campylorhynchus nuchalis	5	38			1	2														
Catharacta antarctica	2	5																		
Ceryle rudis	3	38					4	34	1.59	27	84.4	27	5	57	8.1	57	39.5	27	6	33
Chaetops frenatus					1.1	34							2	57	5.94	57				
Chaetura pelagica	4	20							0.46	27	23.6	27	4.07	20	1.92	57	49.5	27	15	33
Chlorocichla flavicollis	2	5							1.48	27	45.3	27			4.18	57				
Chrysomma sinense	12	31									16	31								
Climacteris affinis	5	51	5	51							21	51	2	57	2.86	57				
Climacteris erythrops	4	51	4	51					0.88	27	23.3	27	2	57			43	27	8.25	33
Climacteris melanurus	3	51	3	51					0.86	27	31.9	27	2	57	4.35	57				
Climacteris picumnus	3	51	3	51					1	27	34.9	27	3	57	4.05	57	30	27	13.93	33
Climacteris rufus	4	51	4	51					1.03	27	33.3	27	2	57	4.18	57	43	27	7.75	33

Colaptes campestris	2.67	5					5	21					6	21						
Coracina maxima	6	51	12	51	2	36			2.2	27	134.7	27					50	27		
Corcorax melanorhamphos	20	51	20	51	1	40			5.2	27	349.1	27	4.3	39	18.4	94	44.25	27	16.3	33
Corvus brachyrhynchos	12	51	12	51			8	16	7.17	27	438.5	27	4.68	57	17.5	57	49.5	27	16.33	33
Corvus caurinus	3	51	3	51					7.43	27	391.5	27	4.02	14	16.7	57	49.8	27	16.75	33
Corvus corone	8.3	5					3	3	8.51	27	485.9	27	4.5	15	19.8	57	51.45	27	19.17	33
Corythaeola cristata					1	34							2	57	54	57				
Cracticus nigrogularis	4	51	12	51					3.02	27	123	27			9.8	57	51	27	22.16	33
Cracticus torquatus	4	51	4	51					2.78	27	89.82	27			7.8	57	49	27	20.17	33
Crotophaga ani	7	51	12	51					1.56	27	111.7	27	4.3	57	13.2	57	23.55	27		
Crotophaga major	5.2	73	10.2	73	2.43	74							7.2	74	29.5	74	20.2	73		
Crotophaga sulcirostris	9	51	20	51							80	51	5.5	86						
Cyanocorax beecheii	4	51	4	51			3	70												
Cyanocorax caeruleus	4	51	4	51							272	51							36	33
Cyanocorax chrysops	10	51	10	51							150	51					41	84		

Cyanocorax cristatellus	10	1											5.7	1						
Cyanocorax dickeyi	16	51	16	51							172.5	51								
Cyanocorax melanocyaneus	11	51	11	51							97.5	51								
Cyanocorax morio	10	90							4.8	27	204	27	4	57	10.3	57	42	27		
Cyanocorax sanblasianus	6	51	6	51							107	51			7.4	57				
Cyanocorax yncas	10	51	10	51							79	51	4	57	7.1	57			10.7	33
Cyanocorax yucatanicus	8	51	8	51							116.5	51								
Cyanopica cyanus					1.55	85							6	57	5.5	57				
Cyanoramphus saisseti	1.6	5																		
Cypsnagra hirundinacea							8	22					2.9	22						
Dacelo leachii	12	51	12	51					4.23	27	309	27	2.58	57	33	57	61.5	27		
Dacelo novaeguineae	4	51	4	51			6	50	4.31	27	334.5	27	2.92	57	30.4	57	60.5	27	15.24	33

Daphoenositta chrysoptera	12	51	12	51					0.61	27	11.7	27	3	57			33.5	27	6.917	33
Donacobius atricapilla							2	45	1.15	27	36.8	27	2	45	3.8	45	34.5	27		
Entomyzon cyanotis	2	5							2.23	27	105.6	27	2.56	57	7.9	57	40	27	9.125	33
Eopsaltria australis	4	51	4	51					0.86	27	20.25	27	2	57	2.73	57	28.7	27	14.65	33
Eopsaltria georgiana	5	51	5	51			5	76	0.75	27	19.77	27	2	57	2.59	57	27	27	18.35	33
Eopsaltria griseogularis	4	51	4	51					0.83	27	21.83	27	2	57						
Erythropygia coryphaeus	2.18	5							0.72	27	23.05	27					26.5	27		
Falco columbarius	3	51	3	51					3.09	27	157.4	27	4	57	22	57	59.5	27		
Falco peregrinus	1	5							6.19	27	743.1	27	3.5	57	48	57	68.75	27		
Fulica atra	3	51	10,000	51					2.85	27	531	27	8	57	36.5	57	53	27	20.6	33
Gallinula chloropus					2.2	54			2.4	27	351	27	7	57	22.3	57	65.75	27	18.6	33
Gallinula mortierii	17	51	17	51	1	68							6.36	57	45	57				
Gallinula tenebrosa	2	51	50	51					2.71	27	531.5	27	8.01	57	34	57	26	27	8.98	33
Gallirallus australis	3	51	3	51					5.11	27	899.3	27	2.3	57	52.6	94	27.75	27		
Gallirallus sylvestris	3	51	2	51					2.9	27	496	27	2.5	57	29	57	23.5	27		

Gerygone mouki	3	5											2.5	57					8.88	33
Gymnorhina tibicen	5	51	300	51			5	28	4.65	27	286.5	27	4	57	16.2	57	48.5	27	23.8	33
Gymnorhinus cyanocephalus	250	51	250	51					3.51	27	105	27	3.7	57	7	57	37	27	14.58	33
Haematopus ostralegus	11.4	5							4.52	27	514.5	27	2.77	57	46.7	57	55.5	27		
Halcyon chelicuti	2	5											4	57	5.7	57				
Hamirostra melanosternon	1	5							10.35	27	1196	27								
Hypopyrrhus pyrohypogaster	5	5											3.1	66	7	66				
Ictinia mississippiensis	3	51	15	51					3.69	27	278	27	2	57	27	57	60.75	27		
Lamprotornis pulcher	20	89					12	89					4	57	4.4	57				
Lamprotornis superbus	6	34			10.2	34							3.5	57	4.5	57				
Lanius excubitoroides	5.5	5			3.2	92							2.82	92					3	33
Lichenostomus melanops	7	51	7	51					0.92	27	32.35	27	2	57			29	27	15.28	33

Lichenostomus penicillatus	3	51	12	51					0.83	27	19.4	27	2.31	57	2.45	57	26.4	27	15.89	33
Lichenostomus virescens	1	5							0.92	27	23.4	27	2.29	57			26.6	27	10.45	33
Loxioides bailleui	4	5											2	57	4	57				
Lybius leucocephalus	11.6	5					4	34					2	57	5.4	57				
Lybius torquatus					1	34			1.16	27	51.7	27	3.5	57	4.2	57	52.5	27		
Malurus alboscapulatus	2.5	26							0.47	27	8	27	2.67	26			41.5	27		
Malurus amabilis	3	51	3	51									2.5	52					12	33
Malurus coronatus	3	51	3	51	4.5	46			0.475	27	9	27	2.5	57	1.46	57	24	27	5.534	33
Malurus cyaneus	3	51	3	51			4	32	0.47	27	9.3	27	3.5	75	1.41	57	26.85	27	10.46	33
Malurus elegans	4	51	4	51					0.57	27	10.08	27	2.5	53	1.11	57	27.25	27	16	33
Malurus lamberti	3	51	3	51	1.52	43	8	43	0.46	27	7.9	27	3.5	57	1.3	57	25.4	27	10.97	33
Malurus leucopterus	3	51	3	51					0.39	27	7.4	27	3.5	75	1.09	57	24	27	5.97	33
Malurus melanocephalus	3	51	3	51			2	69	0.45	27	7.9	27	3.5	57	1.14	57	24.75	27	7.69	33
Malurus pulcherrimus	3	51	3	51			3	11	0.42	27	9.2	27	3	57	1.25	57	25.5	27	7	33

Malurus splendens	3	51	3	51	0.47	87			0.45	27	9.43	27	3	75	1.44	57	26.35	27	11.01	33
Manorina melanocephala	8	51	8	51	1	4			1.86	27	60.3	27	2.9	57	5.35	57	32	27	12.45	33
Manorina melanophrys	11	51	11	51	4.9	18			1.14	27	30.45	27	2	57	3.15	57	27.7	27	13.63	33
Melanerpes formicivorus	4	51	4	51	3.6	47			1.99	27	79.65	27	5.06	57	5.1	57	45	27	17.25	33
Melanodryas cucullata	3	51	3	51					0.8	27	21.25	27	2.5	57	2.9	57	28.75	27	9.617	33
Melanodryas vittata	3	51	20	51					1	27	20	27	3	57	3.19	57	30.5	27		
Melithreptus brevirostris	5.5	65							0.68	27	12.6	27	3	57	1.51	57			12.18	33
Merops albicollis					3	34							6	57						
Merops apiaster	2.3	38			3.5?	41			0.88	27	56.6	27	5.7	57	6.5	57	50.5	27	5.917	33
Merops bullockoides	2.8	38			1.52	25													7	33
Merops bulocki	3.2	38			1	34														
Merops nubicus					1	34							3.5	57	5.8	57				
Merops orientalis					1	13			0.48	27	14.65	27	5	57	3.11	57				
Merops ornatus	1000	51	1000	51			6	8	0.62	27	26.9	27	4.66	57	4.1	57	53.6	27		

Merops pusillus	1	5					0.41	27	15.1	27	4.4	57	2.57	57	42.25	27	7	33
Mesopicos griseocephalos	2	5									3	57	3.8	57				
Microeca fascinans	1.7	5					0.54	27	14.57	27	2	57			35.65	27		
Mohoua albicilla	4	51	10	51							3	57	2.65	57				
Mohoua ochrocephala	3	51	40	51							3	57	3.55	57				
Monias benschi	4	78					2	27	138	27								
Myiopsitta monachus	5	51	5	51			4.08	27	173	27	6	57	7	57	73	27	22.1	33
Neothraupis fasciata	3.6	5									2.33	61						
Notiomystis cincta	2	5									4	57	3.1	57				
Parabuteo unicinctus	7	51	7	51	7	19	7.98	27	865	27	2.84	57	50	57	74.5	27	15	33
Pardalotus striatus	2.5	5					0.52	27	9	27	4	57	1.9	57	43	27	6.025	33
Parus fasciiventer	2.96	5									3	57						
Parus niger	4	5			3	82					3.6	57	1.94	57				
Perisoreus canadensis	3	51	3	51			2.53	27	71.7	27	3.02	57	6.7	57	38.5	27		
Philetairus socius	300	51	300	51	5	67					3.6	57	2.57	57			11	33

Phoeniculus purpureus							4	34	1.95	27	75.6	27	3.2	57	4	57	47.5	27		
Phoenicurus ochruros	1	5			1	58							4.56	58						
Pholidornis rushiae					3	34							2	57	0.73	57				
Phylidonyris novaehollandiae	3	51	15	51					0.9	27	20.25	27	2.5	57	2.56	57	28	27		
Picoides borealis	5	51	5	51	3.57	60			1.66	27	48	27	3.26	57	4.3	57	37.5	27	16.1	33
Picoides pubescens	1	5							1.21	27	27.7	27	4.79	57	2.5	57	33	27		
Platysteira peltata	2	5											1.9	57	1.98	57			7	33
Plocepasser mahali	4	51	4	51	3	56			1.23	27	43.3	27	2.5	57	3.31	57	36	27	10	33
Polihierax semitorquatus	3.3	9							1.47	27	51.2	27	3.06	57	8.4	57	58.5	27		
Pomatostomus ruficeps	13	51	20	51	6.16	81			2.35	27	56	27	4	57	4.15	57	43	27	8.29	33
Pomatostomus superciliosus	13	51	13	51					1.52	27	43.2	27	3	57	3.58	57	34.25	27	14.42	33
Pomatostomus temporalis	15	51	15	51	1.89	12	8	12	1.9	27	75	27	3	57	5.25	57	42.25	27	13.29	33
Porphyrio martinica	9	51	9	51			8	42	2.47	27	236	27	1.7	57	93	57	26	27		

Porphyrio porphyrio	5	51	5	51					4.7	27	744.1	27	4	57	41.5	57	56.25	27	9	33
Prinia subflava	1.1	5											3.3	57	1.07	57			8.25	33
Prunella collaris	2.1	38			1.47	64	4	64					2.57	64						
Prunella modularis	2.5	38			1	7			0.78	27	19.7	27	4.2	7	2.13	57	24.25	27		
Psaltriparus minimus	40	51	40	51					0.35	27	5.3	27	6.3	57	0.72	57	30.5	27		
Pseudoleistes virescens							4	29	2.01	27	79.95	27								
Pseudonigrita arnaudi	12	51	12	51							20.5	51	3.5	57	1.84	57				
Pseudopodoces humilis	4.2	5			1.2	93							6.6	93						
Psophia leucoptera	7	51	7	51																
Pycnonotus barbatus	1.9	5							1.16	27	43	27	2.5	57	3.44	57	28	27	12	33
Ramphocelus carbo	6	5							1.13	27	24.25	27					24	27		
Ramphocinclus brachyurus	2.4	5					3	83												
Rhynochetos jubatus	3	5							6.7	27	860	27	1	55			36	27		
Schetba rufa	2.6	5					4	23												
Seiurus aurocapilla	1	5							0.7	27	18.8	27	4.31	57	2.59	57	20.95	27		
Semnornis ramphastinus	2.7	71	3.1	71			2	71	1.91	27	97.7	27	3	57			59.5	27		

Sericornis frontalis	6	51	6	51					0.76	27	11.4	27	3	88	2.45	57	30.5	27	17.6	33
Sialia mexicana	3	51	125	51					0.84	27	26.45	27	5.06	57	3	57	35.5	27	8.67	33
Sitta pygmaea	2.5	38	26	51					0.55	27	10.6	27	7.08	57	1.1	57	33	27	8.2	33
Smicrornis brevirostris	3.5	5							0.29	27	5.3	27	3	57	1.03	57	38	27	7.39	33
Sphecotheres viridis	7.7	5							2.24	27	121.5	27					30.5	27	18	33
Spizella passerina	25	5											3.7	57	1.6	57				
Stactolaema leucotis					1	34							4	57	4.1	57				
Stipiturus malachurus	3	51	3	51	1	59			0.4	27	7.3	27	3	59	1.23	57				
Struthidea cinerea	9	51	15	51	4.5	17			2.98	27	132	27	3.5	17	7.9	94	36	27	25	33
Struthio camelus					2	34									1500	57				
Sylvia undata	1	5											4	57	1.56	57				
Tangara inornata	2	5																		
Tanysiptera sylvia	3	51	3	51	1	49			1.14	27	49.6	27	2.99	57			54.5	27		
Tetraophasis szechenyii							3	91					7.5	57	75	57				
Todiramphus macleayii	2	5							1.07	27	37.3	27	4.28	57			47.5	27		

Todus mexicanus	1	5							0.4	27	5.83	27					41	27	12.6	33
Trachyphonus erythrocephalus					1.5	34							4.5	57	4.7	57				
Tregellasia capito	6	51	6	51					0.77	27	14.17	27	2	57	2.3	57	33	27	13.18	33
Turdoides bicolor					3.5	72							3	72						
Turdoides caudata	8.5	62			0.61	79							4.18	62	2.94					
Turdoides jardineii					3	34			2.08	27	78	27	3.1	57	4.94	57	34.75	27	4.16	33
Turdoides plebejus					2	34							3	57	3.65	57				
Turdoides striata	7.2	5					4	6					5	30					16.5	33
Vanellus chilensis	3.2	77											3.2	77						
Yuhina everetti	4.2	44			2	44	8	44					2.91	44						

References

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Table S2.

PGLS model of body mass of 135 species birds associated with life history traits. Significant predictors are marked in bold.

Predictors	Body mass				
	λ	β	t	R^2	P
Clutch size	0.960 $^{<0.001, 1}$	−0.012	–0.020	<0. 001	0.984
Egg size	0.996 $^{<0.001, 1}$	**1.278**	**27.193**	**0.882**	**<0.001**
Developmental time	0.986 $^{<0.001, 1}$	**1.350**	**4.064**	**0.135**	**<0.001**
Longevity	1 $^{<0.001, 1}$	**0.535**	**2.486**	**0.081**	**0.015**

Table S3.

PGLS model of group size of 174 species of birds associated with life history. Significant predictors are marked in bold.

Predictors	Average group size				
	λ	β	t	R^2	P
Clutch size	$0^{<0.001, 1}$	–0.898	–1.314	0.034	0.195
Egg size		–0.937	–1.824	0.064	0.074
Developmental time		0.005	0.010	<0. 001	0.992
Longevity		0.505	1.785	0.061	0.081
Body mass		**0.845**	**2.122**	**0.084**	**0.039**

Table S4.

PGLS model of max group size of birds associated with life history in 96 species. Significant predictors are marked in bold.

Predictors	Max group size				
	λ	β	t	R^2	P
Clutch size	0 $^{<0.001, 1}$	**2.937**	**2.291**	**0.127**	**0.028**
Egg size		0.607	0.588	0.010	0.560
Developmental time		–0.295	–0.289	0.002	0.774
Longevity		0.318	1.821	0.679	0.501
Body mass		–0.387	0.828	0.006	0.643

Table S5.

PGLS model of relative brain size of birds associated with life history traits in 119 species. Significant predictors are marked in bold.

Predictors	Relative brain size				
	λ	β	t	R^2	P
Clutch size	0.851 $^{<0.001,\ 1}$	0.013	0.112	<0. 001	0.911
Egg size	0.888 $^{<0.001,\ 1}$	**0.074**	**2.713**	**0.073**	**0.008**
Developmental time	0.957 $^{<0.001,\ 1}$	0.128	1.839	0.031	0.069
Longevity	0.962 $^{<0.001,\ 1}$	0.733	1.441	0.030	0.155
Body mass	0.879 $^{<0.001,\ 1}$	**0.044**	**0.017**	**0.053**	**0.012**

Figure S1. The phylogenetic tree of the 197 species of cooperatively breeding birds used in the comparative analysis.