

# A long-term study of gentoo penguin (*Pygoscelis papua*) population trends at a major Antarctic tourist site, Goudier Island, Port Lockroy

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Michael J Dunn<sup>1\*</sup>, Jaume Forcada<sup>1</sup>, Jennifer A Jackson<sup>1</sup>, Claire M Waluda<sup>1</sup>, Camilla Nichol<sup>2</sup>, Philip N. Trathan<sup>1</sup>

<sup>1</sup> British Antarctic Survey, Natural Environment Research Council, Madingley Road, Cambridge CB3 0ET, UK

<sup>2</sup> UK Antarctic Heritage Trust, High Cross, Madingley Road, Cambridge CB3 0ET, UK

\* Corresponding author E-mail:mdunn@bas.ac.uk

**Supplementary Table S1** Model selection for productivity. Models are expressed as formulas with number of chicks ('chicks') as response variable as a function of number of nests and zero or more explanatory variables, which include season ('syear') as a standardized continuous variable, type of colony ('type') –visited or not visited -, surface air temperature ('airtemp') and day of minimum and maximum sea ice extent ('iceminday', 'daymax'). Variables are fitted as linear or smoothed terms (expressed as s(variable)). For each model, the log-likelihood, number of parameters (np), AIC and  $\Delta$ AIC is shown

model	log-lik.	np	AIC	deltaAIC
chicks ~ offset(lognest) + type + s(visitors, by = type)	-246.2	6	504.4	75
chicks ~ offset(lognest) + type + s(visitors, by = type)	-246.2	6	504.4	75
chicks ~ offset(lognest) + type + s(visitors)	-246.2	5	502.4	73
chicks ~ offset(lognest) + type + s(syear, by = type) + s(visitors, by = type)	-241.6	9	501.1	71.7
chicks ~ offset(lognest) + type	-246.3	4	500.7	71.3
chicks ~ offset(lognest) + type + s(syear, by = type)	-243.4	7	500.6	71.2
chicks ~ offset(lognest)	-246.3	3	498.7	69.3
chicks ~ offset(lognest) + type + s(syear)	-242.9	5.8	497.4	68

chicks ~ offset(lognest) + s(syear, by = type)	-242.9	5.7	497.3	67.9
chicks ~ offset(lognest) + s(syear)	-243.6	4.6	496.4	67
chicks ~ offset(lognest) + s(iceminday, by = type)	-242.1	6	496.2	66.8
chicks ~ offset(lognest) + type + s(iceminday)	-241.5	6.3	495.6	66.2
chicks ~ offset(lognest) + s(iceminday)	-241.5	5.3	493.6	64.2
chicks ~ offset(lognest) + s(syear) + s(iceminday)	-235.4	9.6	490	60.6
chicks ~ offset(lognest) + s(airtemp)	-233.4	9.1	485	55.6
chicks ~ offset(lognest) + type + s(syear) + s(airtemp)	-221.1	13.9	469.9	40.5
chicks ~ offset(lognest) + s(syear, by = type) + s(airtemp)	-220.6	14.1	469.5	40.1
chicks ~ offset(lognest) + s(syear) + s(airtemp)	-221	13	468	38.6
chicks ~ offset(lognest) + s(syear, by = type) + s(airtemp) + s(iceminday)	-214.5	17.4	463.9	34.5
chicks ~ offset(lognest) + s(syear) + s(airtemp) + s(iceminday)	-213	16.2	458.3	28.9
chicks ~ offset(lognest) + type + s(syear) + s(visitors) + s(airtemp) + s(daymax)	-200	21.2	442.3	12.9
chicks ~ offset(lognest) + type + s(syear) + s(visitors) + s(airtemp) + s(iceminday)	-200.3	20.6	441.8	12.4
chicks ~ offset(lognest) + s(syear) + s(visitors) + s(airtemp) + s(iceminday)	-200.5	19.7	440.2	10.8
chicks ~ offset(lognest) + s(syear) + s(visitors) + s(airtemp) + s(daymax)	-197.7	21	437.5	8.1
chicks ~ offset(lognest) + s(syear) + s(visitors) + s(iceminday) + s(daymax)	-195.5	20.3	431.7	2.3
chicks ~ offset(lognest) + s(syear) + s(iceminday) + s(daymax)	-194.2	20.5	429.4	0

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**Supplementary Table S2** Model selection for nest counts. Models are expressed as formulas with number of nest ('nests') as response variable as a function of zero or more explanatory variables, which include season ('syear') as a standardized continuous variable, type of colony ('type') –visited or not visited -, surface air temperature ('airtemp') and day of minimum sea ice extent ('iceminday'). Variables are fitted as linear or smoothed terms (expressed as s(variable)). For each model, the log-likelihood, number of parameters (np), AIC and  $\Delta$ AIC is shown

	model	log-lik.	np	AIC	deltaAIC
1	nests ~ s(syear) + s(visitors) + s(iceminday) + s(daymax)	-271.1	7	556.2	117.5
2	nests ~ s(syear, by = type) + s(airtemp) + s(iceminday)	-270.8	7	555.6	116.9
3	nests ~ s(syear) + s(visitors) + s(airtemp) + s(iceminday)	-270.8	7	555.6	116.9
4	nests ~ s(syear) + s(visitors) + s(airtemp) + s(daymax)	-270.7	7	555.3	116.6
5	nests ~ s(syear, by = type) + s(airtemp)	-270.8	6	553.7	115
6	nests ~ s(syear) + s(airtemp) + s(iceminday)	-270.8	6	553.6	114.9
7	nests ~ s(iceminday, by = type)	-271.6	5	553.1	114.4
8	nests ~ s(visitors, by = type)	-271.5	5	553	114.3
9	nests ~ s(syear, by = type)	-271.4	5	552.8	114.1
10	nests ~ s(syear) + s(iceminday)	-271.2	5	552.5	113.8
11	nests ~ s(syear) + s(airtemp)	-270.9	5	551.7	113
12	nests ~ s(iceminday)	-271.6	4	551.2	112.5
13	nests ~ s(airtemp)	-271.5	4	551.1	112.4
14	nests ~ s(visitors)	-271.5	4	551	112.3
15	nests ~ s(syear)	-271.4	4	550.8	112.1
16	nests ~ 1	-272	3	550	111.3
17	nests ~ type	-229.6	4	467.2	28.5
18	nests ~ type + s(iceminday)	-226.1	5.1	462.3	23.6
19	nests ~ type + s(visitors)	-225.5	5	461	22.3
20	nests ~ type + s(visitors, by = type)	-221.2	8.5	459.5	20.8
21	nests ~ type + s(visitors, by = type)	-221.2	8.5	459.5	20.8
22	nests ~ type + s(syear)	-224.4	5	458.9	20.2
23	nests ~ type + s(syear, by = type)	-218.7	9.1	455.5	16.8
24	nests ~ type + s(syear, by = type) + s(visitors, by = type)	-216	11.4	454.9	16.2
25	nests ~ type + s(syear) + s(visitors) + s(airtemp) + s(iceminday)	-209	12.7	443.5	4.8
26	nests ~ type + s(visitors) + s(airtemp) + s(daymax)	-211.7	9.7	442.9	4.2
27	nests ~ type + s(syear) + s(visitors) + s(airtemp) + s(daymax)	-210.2	10.6	441.7	3
28	nests ~ type + nest_1 + s(syear) + s(airtemp) + s(daymax)	-209.8	10.9	441.3	2.6
29	nests ~ type + s(syear) + s(airtemp)	-211.1	9.2	440.7	2
30	nests ~ type + s(nest_1) + syear:visitors + s(airtemp) + s(daymax)	-209.1	11.1	440.3	1.6
31	nests ~ type + s(syear) + s(airtemp) + s(daymax)	-210.2	9.8	439.9	1.2
32	nests ~ type + syear:visitors + s(airtemp) + s(daymax)	-209.3	10	438.7	0

**Supplementary Table S3** Gentoo penguin pairs: visited and control colonies, Goudier Island, Port

Lockroy, 1996/97 - 2016/17

Season	Colony									
	Boat	Base	Mast	Screen	Nissen	Anemometer	Control 1	Control 2	Control 3	Control 4
1996/97	175	65	154	65	17	80	66	20	28	56
1997/98	174	62	153	69	20	79	63	19	27	57
1998/99	176	62	153	65	13	76	62	17	27	53
1999/00	192	69	167	74	13	83	66	25	36	54
2000/01	212	71	195	103	0	99	76	35	46	71
2001/02	127	10	103	32	0	37	42	18	3	31
2002/03	219	55	142	80	11	40	106	32	38	69
2003/04	182	50	141	68	4	34	35	106	46	56
2004/05	149	55	125	66	1	33	95	29	37	55
2005/06	167	63	123	70	0	30	104	24	39	61
2006/07	152	61	86	62	0	40	41	25	38	52
2007/08	169	52	123	66	0	15	31	69	37	55
2008/09	159	61	125	66	0	14	55	19	36	81
2009/10	199	65	117	65	7	36	47	20	41	65
2010/11	231	36	105	86	0	0	71	12	34	52
2011/12	217	55	114	83	0	42	43	18	31	55
2012/13	193	50	104	70	0	29	43	14	31	52
2013/14	154	48	113	69	0	31	36	10	29	50
2014/15	176	59	134	84	0	17	55	13	23	51
2015/16	159	46	136	71	0	42	42	10	14	39
2016/17	151	48	140	70	0	12	65	7	12	43

**Supplementary Table S4** Gentoo penguin chick numbers: visited and control colonies, Goudier Island,

Port Lockroy, 1996/97 - 2016/17

Season	Colony									
	Boat	Base	Mast	Screen	Nissen	Anemometer	Control 1	Control 2	Control 3	Control 4
1996/97	269	84	243	94	22	104	101	26	47	90
1997/98	304	103	249	103	33	124	95	32	41	93

1998/99	189	66	94	58	3	60	72	14	28	58
1999/00	263	80	227	102	2	117	96	35	39	79
2000/01	314	98	281	147	0	133	118	52	61	111
2001/02	62	9	17	5	0	39	20	6	1	10
2002/03	331	81	221	118	7	62	160	52	55	99
2003/04	298	79	224	113	1	56	51	140	57	86
2004/05	228	70	168	92	1	34	120	34	54	76
2005/06	267	97	190	115	0	40	131	29	56	71
2006/07	208	91	131	90	0	51	71	39	65	70
2007/08	232	72	163	81	0	15	27	73	47	67
2008/09	219	102	148	99	0	18	69	33	54	94
2009/10	280	97	154	89	0	41	66	34	56	82
2010/11	233	34	120	99	0	0	58	9	9	51
2011/12	247	58	139	77	0	33	45	19	33	75
2012/13	232	68	143	113	0	40	64	25	39	74
2013/14	182	61	118	85	0	29	30	8	25	53
2014/15	107	67	164	99	0	16	23	59	20	62
2015/16	135	41	97	55	0	32	32	6	10	39
2016/17	135	45	125	64	0	9	57	5	7	37

**Supplementary Table S5** Gentoo penguin pairs at eight additional colonies located along the

Gerlache Strait within 50 km of Goudier Island, 1996/97-2015/16

Season	Colony							
	Biscoe Point	Cuverville Island	Danco Island	Damoy Point	Georges Point	Jougla Point	Useful Island	Waterboat Point
1996/97	1801				383	1595		
1997/98					397	1545		1455
1998/99				2041	327	1437		4
1999/00	1665					1681		
2000/01	1335				356	1934		
2001/02	692					837		
2002/03	1025			1928		1556		
2003/04	644	5990				1540		
2004/05	753			2022	1995	1306	1861	2456
2005/06	902	6294		2273	2464	1409		
2006/07	877	4420	2506		260	1282		

2007/08			2084	2055	1200	1276	1432	
2008/09		6878	2213	2158	2196	1479	1464	2681
2009/10	2401	6468	3632	2148	2555	1521		
2010/11	2404	990	2115	1823	1158	1091	175	2
2011/12	3081	6336	2558	2091	2408	1172		2509
2012/13	3197	5950	2665	2355	3296	1178		3154
2013/14		7007	2778	2299	2824	1265		3118
2014/15		9176	3248	2560	3443	1345	1810	3915
2015/16		9648	3476	2079	3354	1116		3963

**Supplementary Table S6** Numbers of people (tourists and crew) from all vessels landing on Goudier Island and Jougla Point, Port Lockroy, 1996/97 - 2016/17

Season	People landed	
	Goudier Island	Jougla Point
1996/97	262	102
1997/98	467	450
1998/99	1302	1114
1999/00	2246	1519
2000/01	2575	2949
2001/02	4412	2796
2002/03	6928	6575
2003/04	9570	7593
2004/05	9996	7913
2005/06	12844	8379
2006/07	16770	9981
2007/08	18265	11887
2008/09	15353	8938
2009/10	13841	9078
2010/11	12654	6505
2011/12	17071	8583
2012/13	19248	9135
2013/14	14234	6928
2014/15	19006	7116
2015/16	19834	6986

2016/17	19688	8269
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**Supplementary Table S7** Number of people (tourists and crew) at five additional colonies located along the Gerlache Strait within 50 km of Goudier Island, 2001/02-2016/17

Season	Colony				
	Cuverville Island	Danco Island	Damoy Point	Useful Island	Waterboat Point
2001/02	4115	54	683	202	3758
2002/03	4749	382	1502	145	2920
2003/04	8786	803	741		4258
2004/05	9797	2123	1464	379	4495
2005/06	9768	3172	1266	174	6028
2006/07	13105	3935	1815	910	5929
2007/08	13570	3806	1599	726	4548
2008/09	12794	3232	2323	1236	5207
2009/10	11435	4372	2059	795	1887
2010/11	10495	3016	1886	320	1693
2011/12	11900	5293	4627	64	2041
2012/13	12189	6040	3790	533	1868
2013/14	17101	7699	3082	622	2338
2014/15	15604	7858	4376	912	3076
2015/16	21094	10780	4735	1081	5418
2016/17	27055	12065	8565	1603	7331