Wildlife Biology

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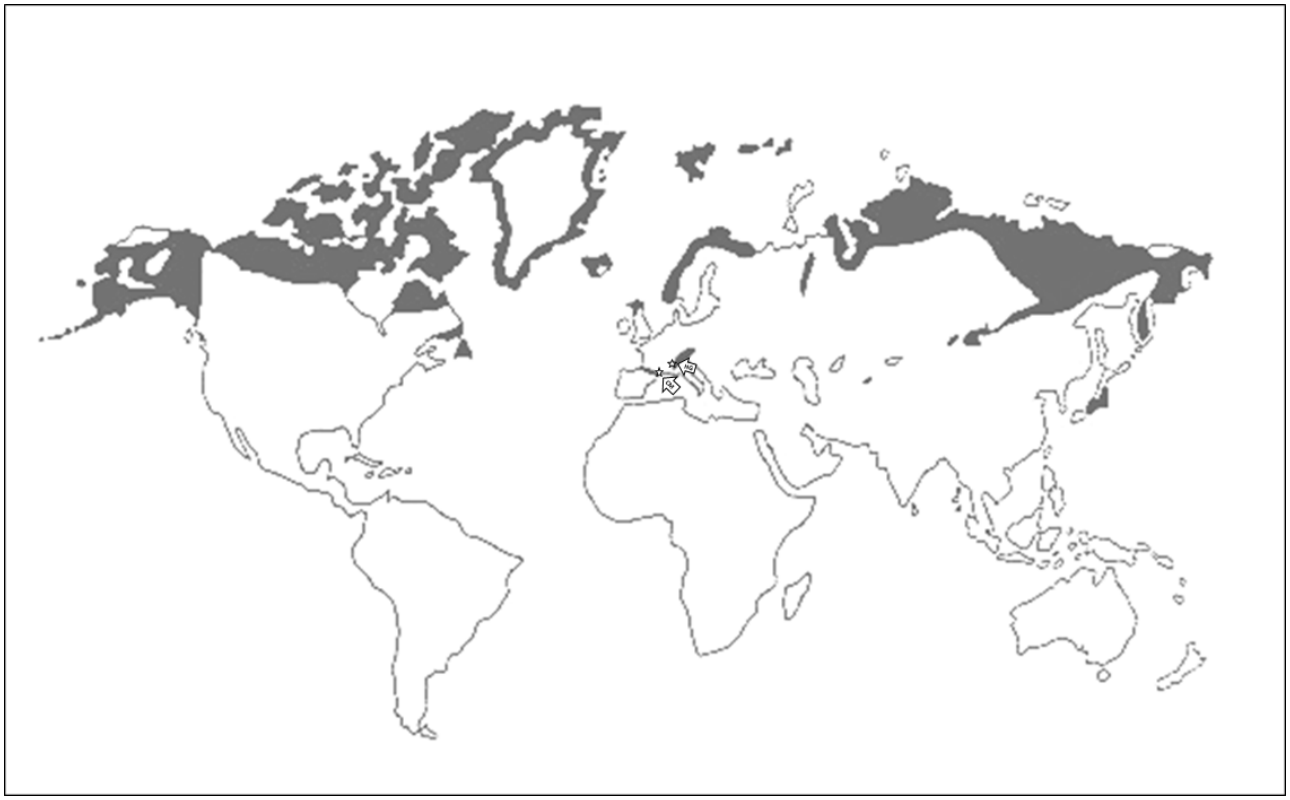
Canonne, C., Novoa, C., Muffat-Joly, B., Resseguier, J., Desmet, J.-F.,Blanch Casadesus, J., Arvin-Berod, M. and Besnard, A. 2020. Life on the edge: common slow pace of life but contrasted trajectories of alpine rock ptarmigan populations at their southern margin. – Wildlife Biology 2020: wlb.00628

Appendix 1

Geographical breeding distribution of the rock ptarmigan *Lagopus muta*. Stars indicate the position of our two study sites: Canigou massif (CM) in the French Pyrenees and Haut Giffre (HG) in the French Alps.



Appendix 2

Sample size details.

Table A1. Total number of radio-equipped rock ptarmigan (n=152) at CM (Canigou massif) by year and age (juvenile: <8 months, yearling: 8–20 months, adult: >20 months) between 1999 and 2017.

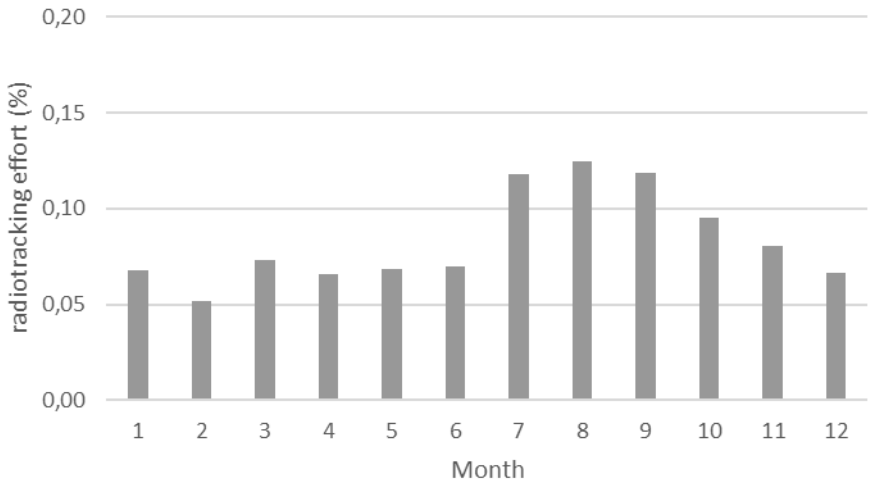
Year	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	Total
A		5	2	2	2	1	4	4	3	7	4	4		4	3	2	4	1	3	55
Y		1	1		1	1	2		1				3		3	1	2	2	1	19
J	1	1	1		1			1	5	6	8	9	9	5	6	10	1	3	11	78
Total	1	7	4	2	4	2	6	5	9	13	12	13	12	9	12	13	7	6	15	**152**

Table A2. Total number of radio-equipped rock ptarmigans (n=153) at HG (Haut Griffe) by year and age (juvenile: <8 months, yearling: 8–20 months, adult: >20 months) between 1999 and 2017.

Year	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	Total
A			3	2	6	4	8	8	6	12	16	3	10	1	4	6	9	3	3	104
Y					1		2	1	3	2	1	3	1		2			1	2	19
J		0							3	3	4	4	4			3	5		4	30
Total	0	0	3	2	7	4	10	9	12	17	21	10	15	1	6	9	14	4	9	**153**

Appendix 3

Fieldwork intensity throughout the year at both sites combined: Canigou massif (CM) in the French Pyrenees and Haut Giffre (HG) in the French Alps. Monitoring included both visual observation and radio-location from distant locations (such as from roads, especially in winter).



Appendix 4

Model selection for the survival analysis of radio-marked rock ptarmigan from 1999 to 2007 in the northern Alps and the eastern Pyrenees presented in the main text. The matrix presented in the main text of the article corresponds to a sub-part of the complete model selection presented in appendix 5. This appendix present the part of the model selection that rely to the analysis presented in the main text, while appendix 5 present the part of the model selection specific to the estimation of the duration of the capture effect. We adopted a sequential backward selection procedure from a general model that included effects, and all interactions between effects: age.season.sex.site + (J1,R) × x + f(Y1,Y) × x +f(A1,A) × x + f(R1,A) × x

(1) Effect of age and season on state at first capture

Initial state()	# of parameters	Deviance	QAIC	QAICc	Delta AIC
age.season	46	1988.11	2080.11	2081.06	0
age	42	2306.89	2391.68	2391.68	310.62

(Note that in multi-state models, selection of initial states is independent from the selection of other parameters, so hereafter we applied a simple age effect for computational reasons.)

(2) Effect of state on physical recapture probability

r()	# of parameters	Deviance	QAIC	QAICc	Delta AIC
f(A A1)	41	2307.29	2390.05	2390.05	0
f(A, A1)	42	2306.89	2391.68	2391.68	1.63

(3) Effects of age, sex and season effect of capture/recapture on survival following capture/recapture

Age:

ax + b	No. of parameters	Deviance	QAIC	QAICc	Delta AIC
f(J1Y1A1R1, JYA) × x	23	2328.72	2374.72	2374.963	0
f(J1Y1A1,JYA) × x + f(R,A) × x	24	2328.16	2376.16	2376.42	1.43
f(J1,J) × x +f(Y1A1,YA) × x +f(R,A) × x	25	2327.51	2377.51	2377.80	2.83
f(J1,J) × x +f(Y1,Y) × x +f(A1,A) × x +f(R,A) × x	26	2327.22	2379.22	2379.53	4.57

Sex and season:

ax + b	No. of parameters	Deviance	QAIC	QAICc	Delta AIC

.	17	2337.0105	2371.01	2371.14	0
season	18	2336.5134	2372.51	2372.66	1.52
sex	18	2336.9917	2372.99	2373.14	2.00

(4) Effect of site on natural survival

s()	No. of parameters	Deviance	QAIC	QAICc	Delta AIC
age.season.sex	26	2327.22	2379.22	2379.53	0
age.season.sex+ site	27	2327.13	2381.13	2381.47	1.93
age.season.sex.site	42	2305.58	2390.38	2390.38	10.85

(5) Site, age and sex by season on natural survival (10 best models from selection with simple age effect on initial states; au=autumn, bp=breeding period, w=winter, aubp = autumn and breeding period together).

Natural survival	No. of parameters	Deviance	QAIC	QAICc	Delta AIC
J.aubp + J.w + YA.aubp.sex + YA.w.sex	11	2339.29	2361.29	2361.35	0
J.aubp + J.w + YA.aubp.sex + YA.w	10	2341.55	2361.55	2361.60	0.24
J.aubp.site + J.w + YA.aubp.sex + YA.w	11	2340.54	2362.54	2362.60	1.25
J.aubp + J.w + YA.aubp.sex + YA.w.site	11	2340.66	2362.66	2362.72	1.37
J.aubp + J.w.site + YA.aubp.sex + YA.w	11	2340.81	2362.81	2362.87	1.52
J.aubp + J.w + YA.bp.sex+ + YA.au + YA.w	11	2340.84	2362.84	2362.90	1.54
J.aubp + J.w + YA.aubp + YA.w	9	2345.12	2363.12	2363.15	1.80
J.aubp + J.w + YA.aubp.sex + YA.w + site	11	2341.31	2363.31	2363.37	2.01
J.aubp + J.w.site + YA.aubp.sex + YA.w.sex	11	2342.22	2364.22	2364.28	2.93
J.aubp + J.w + YA.bp + YA.au + YA.w	10	2344.26	2364.26	2364.31	2.96

Appendix 5

Survival analysis based on 17 states to test for the duration of the capture effect

The model presented here is a more complete version of the one presented in the main text, that aimed at estimating the duration of the effect by testing different thresholds. The initial model consisted of 17 states combining both the age class of the bird (J,Y or A) and whether they were recently radio-equipped (1: less than one month ago, 2: between one and two months, 3: between two and three months, 4+ four months or more). For female adults that were physically recaptured a second or third time (R) we used the same numbering (R1, R2, R3) to indicate when they were recaptured. The two last possible states were 'newly dead' (ND) and 'dead' (D). Recapture here refers to radio-equipped birds that were physically recaptured a second or a third time, all noted R because of low sample size. In our dataset, it included only adult females at states A1, A2 or A4+ that were recaptured in order to mark their brood.

We applied an additive effect of first capture and physical on survival to deal with the fact that captures occurred unevenly across months and seasons (A1 captures: 1.3% winter, 95.3% breeding period, 3.1% autumn; Y1 captures: 94.7% breeding period, 5.3% autumn; J1 captures: 97.2% autumn, 2.8% breeding period; R1 recaptures: 68.6% breeding period, 31.4% autumn). Consequently, the impact of capture on juvenile survival was extrapolated from the effect on yearlings and adults. To test the hypothesis that the impact of capture/physical recapture on survival would lessen after a month, we forced survival from states 1 to 4+ to increase gradually, using a standardized covariate (in model selection noted x).

	J4+	Y4+	A4+	J1	J2	J3	Y1	Y2	Y3	A1	A2	A3	R1	R2	R3	ND	D
J4+	s*(1-a)	s*a	0	0	0	0	0	0	0	0	0	0	0	0	0	1-s	0
Y4+	0	s*(1-a)	s*a	0	0	0	0	0	0	0	0	0	0	0	0	1-s	0
A4+	0	0	s*(1-r)	0	0	0	0	0	0	0	0	0	s*r	0	0	1-s	0
J1	0	0	0	0	s	0	0	0	0	0	0	0	0	0	0	1-s	0
J2	0	0	0	0	0	s	0	0	0	0	0	0	0	0	0	1-s	0
J3	s	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1-s	0
Y1	0	0	0	0	0	0	0	s	0	0	0	0	0	0	0	1-s	0
Y2	0	0	0	0	0	0	0	0	s	0	0	0	0	0	0	1-s	0
Y3	0	s	0	0	0	0	0	0	0	0	0	0	0	0	0	1-s	0
A1	0	0	0	0	0	0	0	0	0	s*(1-r)	0	0	s*r	0	0	1-s	0
A2	0	0	0	0	0	0	0	0	0	0	s*(1-r)	0	s*r	0	0	1-s	0
A3	0	0	s	0	0	0	0	0	0	0	0	0	0	0	0	1-s	0
R1	0	0	0	0	0	0	0	0	0	0	0	0	0	s	0	1-s	0
R2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	s	1-s	0
R3	0	0	s	0	0	0	0	0	0	0	0	0	0	0	s	1-s	0
ND	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Figure A1. Initial state–state transition matrix used in the survival analysis of rock ptarmigan from 1999 to 2007 in the northern Alps and the eastern Pyrenees for the analysis that estimates the duration of the capture effect during the first four month after release. The matrix presented in the main text of the article corresponds to a sub-part of the complete model selection. The departure state at time *t*-1 is presented in rows and the arrival state at time *t* in columns. The transition from one state to another from occasion *t* to *t*+1 was modeled through three successive steps: survival (s), physical recapture (r) and ageing (a). At first capture, birds could be in one of the three following states: J1, Y1 or A1.

We adopted a sequential backward selection procedure from a general model that included effects, and all interactions between effects: age.season.sex.site + (J1,J2,J3,J) × x + f(Y1,Y2,Y3,Y) × x +f(A1,A2,A3,A) × x + f(R1,R2,R3,A) × x

Below is mentioned the part of the model selection that were specific to this model, that is complementary to the selection model of the main text analysis presented in Appendix 4 :

(1) Effect of state on physical recapture probability

r()	# of parameters	Deviance	QAIC	QAICc	Delta AIC
f(A A1, A2)	42	2303.97	2387.97	2388.77	0
f(A, A1, A2)	43	2302.54	2389.38	2389.38	0.60
f(A A1 A2)	41	2307.29	2390.05	2390.05	1.28
f(A A2, A1)	42	2305.58	2390.38	2390.38	1.61
f(A, A1 A2)	42	2306.89	2391.68	2391.68	2.91

Physical recapture probability was two times lower for states A1 and A4+ (adults radio-equipped less than a month ago or at least four months ago, r=0.02; 95% CI: 0.01–0.02) than for state A2 (adults radio-equipped between one and two months ago, r= 0.04; 95% CI: 0.02–0.09).

(2) Effect of duration of the capture effect

To estimate the effect of capture and the duration of this effect, we compared models using different values for the covariate in order to test slopes that corresponded to different durations and timing of the linear effect (ax + b with a the slope and b the intercept).

x	# of parameters	Deviance	QAIC	QAICc	Delta AIC
-1 0 0 0	10	2341.55	2361.55	2361.60	0
-2 -1 -1 0	10	2343.14	2363.14	2363.19	1.60
-2 -1 0 0	10	2343.74	2363.74	2363.79	2.19
-3 -2 -1 0	10	2344.39	2364.39	2364.43	2.84
0 0 0 0	9	2348.50	2366.50	2366.54	4.94

-2 -2 -1 0	10	2346.51	2366.51	2366.55	4.96
-1 -1 -1 0	10	2346.56	2366.56	2366.61	5.01
-1 -1 0 0	10	2346.89	2366.89	2366.94	5.34

(5) Sex, season and duration of capture effect on survival following recapture (R) (with simple age effect on initial states) ax + by + c.

x/y	# of parameters	Deviance	QAIC	QAICc	Delta AIC
-1 0 0 0/ -1 0 0 0.season	13	2334.36	2360.3552	2360.44	0
-1 0 0 0 / -1 0 0 0	12	2338.49	2362.49	2362.56	2.13
-1 0 0 0 / -2 -1 0 0	12	2339.79	2363.79	2363.86	3.42
-1 0 0 0 / -3 -2 -1 0	12	2340.15	2364.15	2364.22	3.78
-1 0 0 0 /-1 0 0 0.sex	13	2338.32	2364.32	2364.40	3.97

Appendix 6

Details on reproduction analysis and models outputs

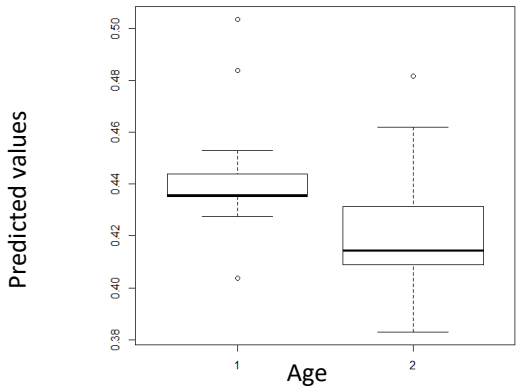
Nest success analysis using a generalized mixed model with a binomial error

Results from the r.squaredGLMM(MuMIn) : The random year effect explained 1.92% of variation while the random effect of hen's identification number (id) effect accounted for very little of the variation. In the model with a fixed age model, the percentage of variance explained was comparable, while in the model with a fixed effect of site, the latest accounted for about 2.3% of the variation.

Age effect :

Random effects group name	Variance	Std.Dev.
Id (109)	< 0.001	< 0.001
Year (18)	0.064	0.253

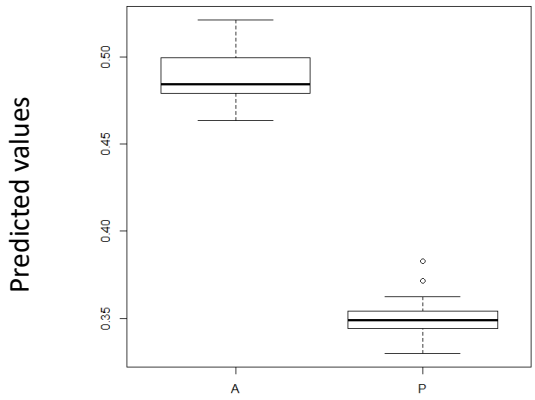
Fixed effects	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	-0.136	0.810	-0.168	0.867
age	-0.088	0.430	-0.203	0.839



Site effect :

Random effects group name	Variance	Std.Dev.
Id (109)	< 0.001	< 0.001
Year (18)	0.035	0.187

Fixed effects	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	-0.048	0.219	-0.218	0.827
siteP	-0.562	0.325	-1.727	0.084 .



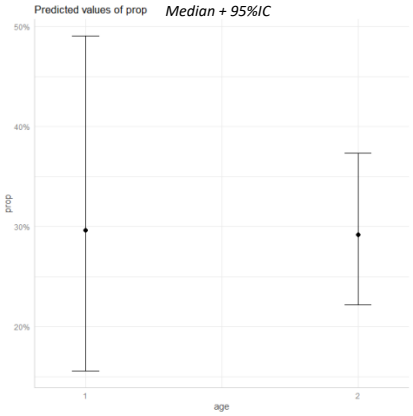
Proportion of hens with chicks at the end of August analysis using a generalized mixed model with a binomial error

Results from the r.squaredGLMM(MuMIn): Both the random effect of the hen's identification and the random year effect explained very little of the variation. In the model with a fixed age model, the percentage of variance explained was comparable, while in the model with a fixed effect of site, the latest accounted for about 5.5% of the variation.

Age effect :

Random effects group name	Variance	Std.Dev.
Id (109)	<0.001	<0.001
Year (18)	<0.001	<0.001

Fixed effects	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	-0.844	0.864	-0.977	0.328
age	-0.021	0.461	-0.045	0.964

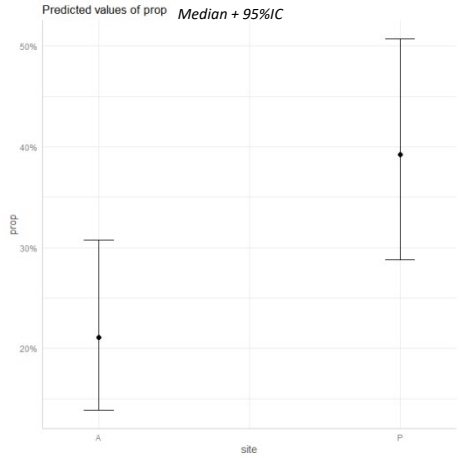


Site effect :

Random effects group name	Variance	Std.Dev.
Id (109)	<0.001	<0.001

Year (18)	<0.001	<0.001

Fixed effects	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	-1.318	0.258	-5.104	<0.001***
siteP	0.879	0.351	2.502	0.012 *



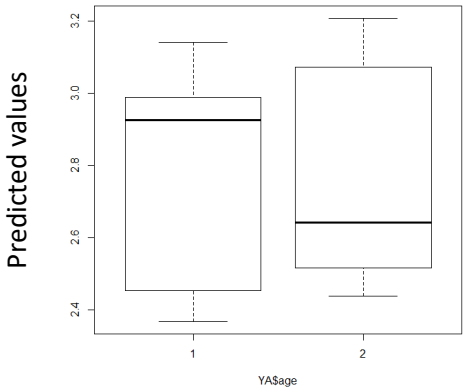
Brood size of hens with chicks at the end of August using a generalized mixed model with a zero-truncated Poisson error

Plots of zero-truncated models results showed good convergence. The over dispersion parameter for the truncated Poisson model was of 1.1, which is acceptable. Because the MuMIn package cannot deal with ZTP, we quantified the percentage of variation explained by the models using a Poisson distributed error. Results from the r.squaredGLMM(MuMIn) : The random year effect explained 1,92% of variation while the random effect of hen's identification number (id) effect accounted for very little of the variation. In the model with a fixed age model, the percentage of variance explained was comparable, while in the model with a fixed effect of site, the latest accounted for about 1.9% of the variation.

Age effect :

Random effects group name	Variance	Std.Dev.
Id (138)	0.017	0.131

Fixed effects	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	1.027	0.251	4.09	<0.001***
age	-0.003	0.133	-0.02	0.984



Site effect :

Random effects group name	Variance	Std.Dev.
Id (138)	0.01126	0.1061

Fixed effects	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	0.916	0.082	11.178	<0.001***
siteP	0.200	0.102	1.956	0.050 .