Journal of Avian Biology

JAV-02037
Tinbergen, J. M., Fokkema, R. W., Pen, I. and Ubels, R. 2019. Sea buckthorn berries *Hippophae rhamnoides* L. predict size and composition of a great tit population *Parus major* L.. – J. Avian Biol. 2019: e02037

Supplementary material

Appendix 1: Priors used and performance of the MCMC

For estimates of the regression coefficients we used so-called weakly informative normal priors with mean zero and standard deviation as specified below. In the regressions explaining variation in the number of breeding birds we took the prior as normal (mean = 0, SD = 40) where doubling the sd of the prior somewhat affected the parameter estimates (<6%), while in all other regressions we choose the prior normal (mean=0, SD=2) for the coefficients. Doubling of the standard deviations in these models did hardly affected the parameter estimates (<1%). For standard deviations and correlations of random effects we used the default priors of the brms package (half-student t with df=3).

Each MCMC model was run in 8 chains with 3000 iterations each, of which 1000 were warm-up iterations. Model convergence and mixing was monitored with Rubin and Gelman's (1996) R-hat statistic and by visual inspection of trace plots. Effective sample size was at least 1000 for all parameters.

Reference:

Gelman, A., and D. B. Rubin. 1992. Inference from Iterative Simulation Using Multiple Sequences. *Statistical Science* 7: 457–511.

Appendix 2: Buckthornberry bush age effects on the number of berries per bush do not exist

Table A2: Parameter estimates for a negative binomial regression with year id and bush id as random effects and age (year sequence -2 to 3) as fixed effect.

	effect	SD or mean	-89% HPDI	+89% HPDI
year_id	random	1.87	0.78	3.59
bush_id	random	0.77	0.18	1.38
intercept	fixed	8.41	7.07	9.73
"age"	fixed	-0.09	-0.79	0.59
shape parameter Theta		0.59	0.44	0.75

Appendix 3: recapture probability

Table A3: Logistic binomial models estimating recapture probability as explained by annual berry abundance (Z-score), sex (male=1, female=0) and season (spring=1, winter=0). The estimates of the selected model (indicated with a star) with their 0.89 HPDI intervals are given. Parameter estimates of model mrp3 (basis of Fig. 4 main text) were used to calculate the predicted mean recapture probability for the corresponding berry abundance, sex and period to correct return rates to apparent survival rates. For explanation of HPDI, WAIC and weight see methods.

	random year	Intercept	berriec	male	spring	male: berriec	spring: berriec	male: spring	berriec: male: spring	waic	deltawaic	weight
mrp3 *	1	1	1	1	1		1	1		112.2	0	0.33
mrp4	1	1	1	1	1			1		112.44	0.24	0.29
mrp1	1	1	1	1	1	1	1	1	1	113.54	1.34	0.17
mrp2	1	1	1	1	1	1	1	1		114.02	1.82	0.14
mrp6	1	1		1	1			1		115.47	3.27	0.06
mrp5	1	1	1	1	1					122.85	10.65	0
estimates mss1	SD	Intercept	beta	beta	beta	beta	beta	beta				
mean	0.2	1.48	0.15	0.78	1.18		0.31	-1.27				
lower 89% HPDI	0.02	1.15	-0.16	0.36	0.65		-0.06	-1.95				
upper 89% HPDI	0.54	1.82	0.45	1.21	1.73		0.68	-0.61				

Appendix 4: Slopes of berry effects on return rate in the first and the second half of the winter

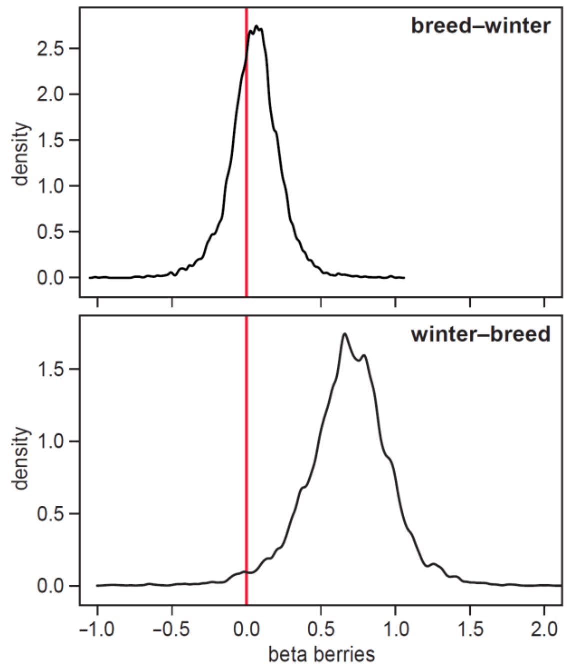

Fig. A4: Density plots of posterior distributions of the slopes (logit scale) of return rate with respect to berry abundance of great tits from the breeding season until midwinter (breed to winter) and from midwinter to the next breeding season (winter to breed) based respectively on model msw2 from Table 2a and on model mws2 from Table 2b. A positive berry effect was strongly supported in the second half of the winter not in the first half.

Appendix 5: Immigration rate of juvenile birds

Table A5: Logistic binomial models explaining the annual immigration rate of juvenile birds in the breeding population from the linear and quadratic term of the berry abundance Z-scores and sex (female= 0 and male= 1). Parameter estimates for model mji3 are given.

	random year	Intercept	berriec	berriec2	female	female *berrie	waic	deltawaic	weight
mji2	1	1	1		1		78.57	0	0.297
mji3	1	1	1	1	1		78.58	0.01	0.296
mji4	1	1			1		78.66	0.09	0.284
mji1	1	1	1	1	1	1	80.38	1.81	0.122
mji7	1	1	1	1			99.85	21.28	0
mji5	1	1					100.01	21.44	0
mji6	1	1	1				100.68	22.11	0
parameters mji3	SD	intercept	beta	beta	beta				
mean	0.64	-0.74	0.27	0.32	0.44				
lower 89% HPDI	0.21	-1.42	-0.42	-0.32	0.26				
upper 89% HPDI	1.55	-0.03	0.93	0.95	0.63				

Appendix 6: Annual berry consumption index

Table A6: Logistic binomial models explaining the annual berry consumption index in the winter population as a function of the linear and quadratic term of berry abundance index Z-scores, and sex (female= 0 and male= 1). Parameter estimates for model mdi1 are given.

	random year	Intercept	berriec	berriec2	female	female *berriec	waic	deltawaic	weight
mdi7	1	1	1	1			77.84	0	0.202
mdi5	1	1					77.86	0.02	0.2
mjd6	1	1	1				77.97	0.13	0.189
mdi1	1	1	1	1	1	1	78.03	0.19	0.183
mjd4	1	1			1		79.68	1.84	0.08
mjd3	1	1	1		1		79.85	2.01	0.074
mjd2	1	1	1	1	1		79.90	2.06	0.072
parameters mdi1	SD	intercept	beta	beta	beta	beta			
mean	1.03	0.54	-0.12	-0.23	-0.01	0.16			
lower 89% HPDI	0.41	-0.51	-1.07	-1.14	-0.17	-0.01			
upper 89% HPDI	2.26	1.55	0.78	0.72	0.15	0.32			

Appendix 7: The effects of berry abundance and berry consumption on individual return rate

Table A7: Multilevel logistic binomial models estimating the effects of berry abundance and berry consumption on individual return rate from December to the next breeding season. Explanatory variables were calculated on the year level (mean year Z-values, DDY = Y-poop and berriec= Y-berry) and the individual level (DDI= I poop score and sex= male). The estimates of the selected model (indicated with a star) with their 0.89 HPDI intervals are given. The model m5* was used to calculate the posterior distributions given in Fig. 7 in the main text.

	random year	random area	Intercept	male	berriec	DDI	DDY	male: berriec	male: DDI	male: DDY	waic	deltawaic	weight
m4	1	1	1	1	1	1	1		1	1	2201.17	0.00	0.20
m5*	1	1	1	1	1	1	1				2201.21	0.04	0.19
m3	1	1	1	1	1	1	1	1		1	2201.53	0.36	0.16
m6	1	1	1	1	1	1			1		2201.84	0.67	0.14
m7	1	1	1	1	1						2201.94	0.77	0.13
m1	1	1	1	1	1	1	1	1	1	1	2202.28	1.11	0.11
m2	1	1	1	1	1	1	1	1	1		2203.53	2.36	0.06
estimates m5	SD	SD	intercept	beta	beta	beta	beta						
mean	0.64	0.36	-0.64	-0.21	0.70	-0.10	-0.32						
lower 89% HPDI	0.22	0.21	-1.14	-0.38	0.23	-0.19	-0.79						
lower 89% HPDI	1.60	0.56	-0.14	-0.03	1.13	-0.01	0.17						

Appendix 8 Associations between components of reproductive performance and the berry abundance in the winters before and after the reproductive event.

Table A8: Associations between components of reproduction and berry abundance in

a) the preceding winter

	beta	lower 89% HPDI	lower 89% HPDI
mean nestling mass day 6 (g)	-0.32	-1.35	0.73
number of nestlings	-0.21	-1.27	0.47
broodmass (g)	-0.29	-1.34	0.36

b) the following winter

	beta	lower 89% HPDI	lower 89% HPDI
mean nestling mass day 6 (g)	-0.18	-1.24	0.90
number of nestlings	0.47	-0.52	1.40
broodmass	0.15	-0.92	1.24

The annual mean was measured when the oldest nestling was 6 days old. All data were in Z-scores. Regression coefficients and their 0.89 HPDI intervals are given.

Appendix 9: The return rate of great tits in relation to the annual density and berry abundance.

Table A9: Logistic binomial models explaining the return rate of great tits in relation to the annual density in the breeding season (Z-score), berry abundance (Z-score) the age-sex groups (juveniles as the reference category) and the interaction between density and the age-sex groups for the whole winter (breeding season till next breeding season). Year was taken as a random effect. Model comparison was done on the basis of the WAIC and the WAIC-weight.

	random year	Intercept	female	male	densc	female *densit	male* density	berriec	female *berrie	male* berriec	waic	deltawaic	weight
mss5	1	1	1	1	1	1	1				124.78	0	0.3977
mss3	1	1	1	1	1	1	1	1			125.11	0.33	0.337
mss1	1	1	1	1	1	1	1	1	1	1	125.79	1.01	0.24
mss2	1	1	1	1	1			1	1	1	132.13	7.35	0.0101
mss6	1	1	1	1				1	1	1	132.53	7.75	0.00823
mss7	1	1	1	1							135.51	10.73	0.00186
mss9	1	1	1	1	1						135.51	10.73	0.00186
mss8	1	1	1	1				1			135.92	11.14	0.00152
mss4	1	1	1	1	1			1	1		136.34	11.56	0.0017
mss10	1	1									728.14	603.36	0
estimates mss5	SD	beta	beta	beta	beta	beta	beta						
mean	0.29	-2.25	1.44	1.27	-0.42	0.16	-0.19						
lower 0.89 HPDI	0.12	-2.54	1.28	1.10	-0.75	-0.01	-0.34						
upper 0.89 HPDI	0.59	-1.59	1.60	1.43	-0.10	0.33	-0.04						
estimates mss3	SD	beta	beta	beta	beta	beta	beta	beta					
mean	0.18	-2.25	1.44	1.27	-0.29	0.16	-0.19	0.21					
lower 0.89 HPDI	0.01	-2.47	1.28	1.10	-0.58	-0.01	-0.38	-0.07					
upper 0.89 HPDI	0.69	-2.03	1.59	1.43	0.01	0.33	-0.01	0.51					

Appendix 10: Apparent survival as calculated from recapture probability and return rate.

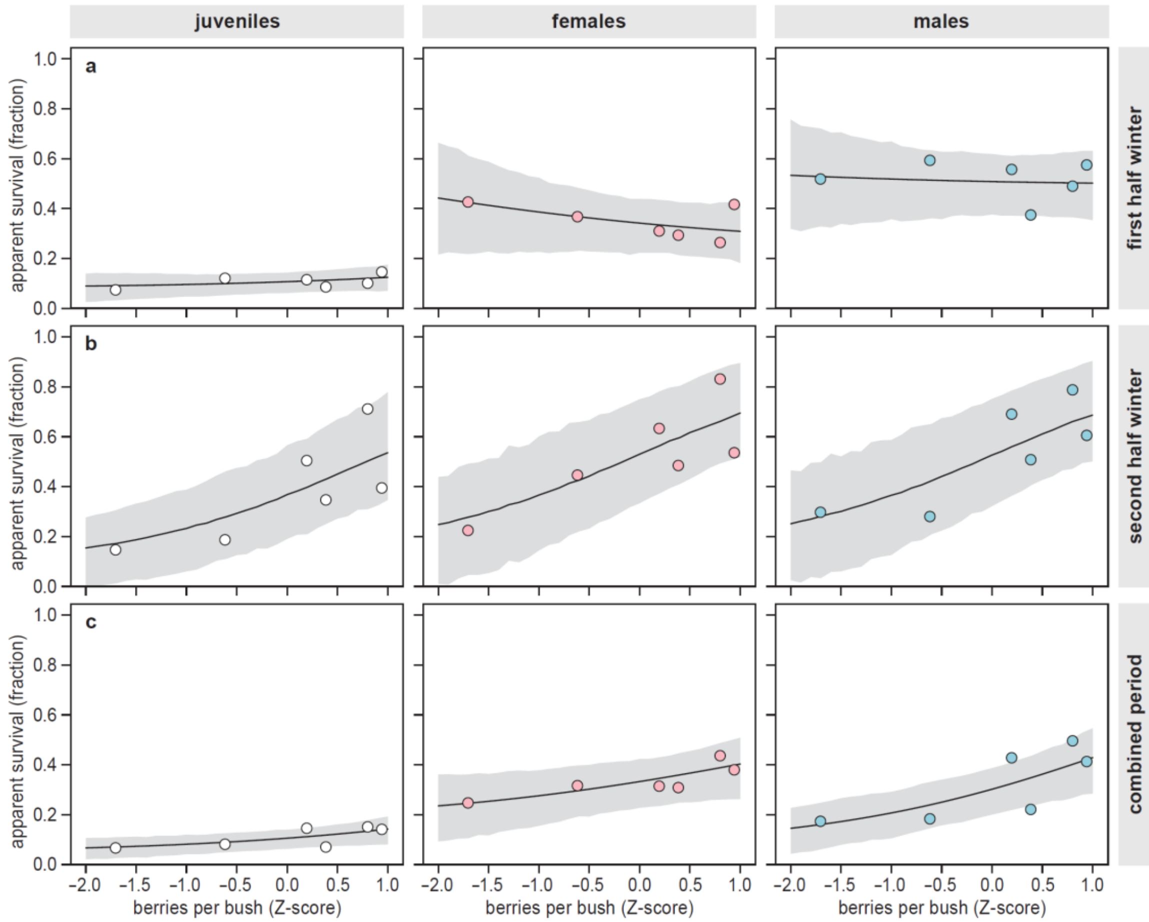

Fig. A10: The apparent survival rate as a function of the berries per bush (Z- score) for first year juvenile, adult female and adult male great tits over: a) the first half of the winter, b) the second half of the winter and c) the combined period. The berry abundance per bush was measured in December. Grey areas are 89% HPDI intervals (see methods) calculated from the posterior distribution of logistic models including the interaction between group and Z-score of the berries for each of the periods separately (see Table 2a, b and c). Apparent survival rates were calculated from the 89% HPDI estimates from return rate (Table 2, Fig. 5) divided by the mean recapture probability for the adequate group and berry density (as calculated from Table A3 model mrp3).