Oikos

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New, L. F., Buckland, S. T., Redpath, S. and Matthiopoulos, J. 2012. Modelling the impact of hen harrier management measures on a red grouse population in the UK. – Oikos 121: 1061–1072.

Appendix 1

Table A1.1. Additional equations for the hen harrier and red grouse models.

$a_t = \frac{\exp\{\xi_0 + \xi_1 0.5G_{f,t} + \xi_2 0.5G_{f,t-1}\}}{1+\exp\{\xi_0 + \xi_1 0.5G_{f,t} + \xi_2 0.5G_{f,t-1}\}}$ *	Aggression of male red grouse, where ξ_0, ξ_1 and ξ_2 relate grouse density prior to hunting and recruitment (G_f) in years t and t–1 to aggression (a_t).
$\lambda_t = \exp\{\gamma_0 - \gamma_1 W_t\}$ *	Rearing rate of red grouse (λ_t), where γ_0 is the natural log of brood size and γ_1 measures the effect of average worm burden (W_t) on reducing rearing rate.
$W_{t+1} = W_{a,t}\phi_{w,t} + A_t\phi_{l,t}$ *,+	Change in parasite burdens from time t to time t–1, where W_a is the autumn parasite burden, A_t is the arrested larvae in autumn of time t, and $\phi_{w,t}$ and $\phi_{l,t}$ are the over-winter survival of adult worms and arrested larvae, respectively.
$\eta_t = \exp(\beta_0 V_t + \beta_1 P_t - \beta_2 H_{Obs,t-1}\phi_{t-1})$ †	Net movement of hen harriers (η_t), where β_0, and β_1 measure the effect of vole (V_t) and pipit (P_t) density on net movement and β_2 measures the effect of harriers surviving from the previous year ($H_{Obs,t-1}\phi_{t-1}$) on net movement.
$\phi_t = \frac{\exp(\alpha_0 + \alpha_1 P_t)}{1+\exp(\alpha_0 + \alpha_1 P_t)}$ †	Harrier survival (ϕ_t), where α_0 incorporates all other sources of mortality and α_1 measures the effect of pipit density on harrier survival.

* equations from New et al. (2009)
† equations from New et al. (2011)
+ values for these parameters were taken from previously published literature (New et al. 2009)

Table A1.2. Parameter values for the MSFR for each species, *j*.

Parameters	m	k	h
Grouse	4.51	1.89×10^{-6}	2.16
Vole	1.04	2.52×10^{-2}	1.24
Pipit	1.14	1.33	1.85

Table A1.3. Priors for the harrier-grouse interaction model.

Θ	Prior
α_0	N(0,1)
α_1	LN(-5.29,0.833)
β_0	Γ(1,50)
β_1	Γ(1,50)
β_2	Γ(1,5)
γ_0	N(0,1)
γ_1	Γ(1,50)
ϕ_a	β(1,1)
ξ_0	U(-4,-2)
ξ_1	U(0,0.02)
ξ_2	U(0.005,0.04)
τ_c	Γ(2.5,0.1)
c	Γ(15,2)

Table A1.4. Parameter estimates and 95% credible intervals for the hen harrier parameters for all four scenarios.

Θ	Predation	Prediction	Partial	Full
α_0	0.37 (–0.65, 1.25)	0.06 (–1.45, 1,45)	0.37 (–0.65,1.25)	0.37 (–0.66, 1.25)
α_1	2.6×10^{-3} (6.6×10^{-4}, 6.2×10^{-3})	3.0×10^{-3} (7.6×10^{-4}, 7.1×10^{-3})	2.7×10^{-3} (7.1×10^{-4}, 6.2×10^{-3})	2.7×10^{-3} (6.8×10^{-4}, 6.1×10^{-3})
β_0	1.3×10^{-3} (5.7×10^{-4}, 1.9×10^{-3})	1.3×10^{-3} (5.5×10^{-4}, 1.9×10^{-3})	1.3×10^{-3} (5.8×10^{-4}, 1.9×10^{-3})	1.3×10^{-3} (5.8×10^{-4}, 1.9×10^{-3})
β_1	1.1×10^{-3} (7.4×10^{-5}, 2.6×10^{-3})	1.1×10^{-3} (7.9×10^{-5}, 2.6×10^{-3})	1.1×10^{-3} (7.6×10^{-5}, 2.6×10^{-3})	1.1×10^{-3} (7.4×10^{-5}, 2.6×10^{-3})
β_2	0.031 (9.8×10^{-4}, 0.10)	0.031 (9.0×10^{-4}, 0.1)	0.031 (9.6×10^{-4}, 0.097)	0.031 (9.2×10^{-4}, 0.097)
ξ_0	–2.2 (–2.6, –2.0)	–2.2 (–2.6, –2.0)	–2.2 (–2.6, –2.0)	–2.2 (–2.6, –2.0)
ξ_1	0.013 (0.0016, 0.019)	0.013 (0.002, 0.019)	0.013 (0.002, 0.019)	0.013 (0.002, 0.019)
ξ_2	0.024 (0.006, 0.039)	0.026 (0.006, 0.039)	0.023 (0.006, 0.039)	0.023 (0.006, 0.040)

Table A1.5. Parameter estimates and 95% credible intervals for the red grouse parameters for all for scenarios.

Θ	Predation	Prediction	Partial	Full
$\gamma_{0,LC}$	1.8 (1.1, 2.3)	1.9 (1.3, 2.4)	1.8 (1.1, 2.3)	1.8 (1.2, 2.3)
$\gamma_{0,LD}$	2.2 (1.5, 2.8)	2.3 (1.7, 2.9)	2.2 (1.5, 2.8)	2.2 (1.6, 2.8)
$\gamma_{0,LM}$	1.7 (1.1, 2.3)	1.9 (1.2, 2.6)	1.7 (1.1, 2.3)	1.7 (1.1, 2.3)
$\gamma_{0,LR}$	1.6 (0.94, 2.3)	1.7 (1.0, 2.3)	1.6 (0.96, 2.3)	1.6 (1.0, 2.2)
$\gamma_{1,LC}$	9.6×10^{-5} (7.7×10^{-7}, 6.1×10^{-4})	9.9×10^{-5} (8.6×10^{-7}, 6.5×10^{-4})	9.1×10^{-5} (7.8×10^{-7}, 5.6×10^{-4})	8.4×10^{-5} (8.1×10^{-7}, 5.1×10^{-4})
$\gamma_{1,LD}$	1.2×10^{-3} (9.3×10^{-6}, 7.2×10^{-3})	1.5×10^{-3} (1.2×10^{-5}, 7.9×10^{-3})	1.1×10^{-3} (9.3×10^{-6}, 6.6×10^{-3})	1.2×10^{-3} (1.1×10^{-5}, 6.6×10^{-3})
$\gamma_{1,LM}$	8.7×10^{-5} (4.9×10^{-7}, 4.9×10^{-4})	1.0×10^{-4} (7.3×10^{-7}, 5.9×10^{-4})	8.8×10^{-5} (5.3×10^{-7}, 5.0×10^{-4})	8.6×10^{-5} (3.8×10^{-7}, 5.1×10^{-4})
$\gamma_{1,LR}$	9.5×10^{-5} (2.4×10^{-8}, 6.1×10^{-4})	1.0×10^{-4} (9.0×10^{-8}, 6.4×10^{-4})	8.8×10^{-5} (3.4×10^{-8}, 5.8×10^{-4})	9.6×10^{-5} (4.5×10^{-8}, 6.5×10^{-4})
$\phi_{a,LC}$	0.32 (0.04, 0.56)	0.34 (0.06, 0.58)	0.31 (0.03, 0.57)	0.32 (0.03, 0.56)
$\phi_{a,LD}$	0.51 (0.23, 0.69)	0.57 (0.34, 0.72)	0.51 (0.23, 0.70)	0.52 (0.23, 0.70)
$\phi_{a,LM}$	0.32 (0.03, 0.60)	0.36 (0.06, 0.61)	0.32 (0.03, 0.60)	0.32 (0.03, 0.59)
$\phi_{a,LR}$	0.51 (0.16, 0.74)	0.57 (0.28, 0.76)	0.50 (0.17, 0.73)	0.52 (0.15, 0.75)
τ_c	11.3 (2.1, 35.3)	18.5 (4.5, 47.6)	10.5 (2.0, 32.3)	8.6 (1.9, 25.3)
c_{LC}	6.6 (4.6, 9.2)	6.7 (4.6, 9.2)	6.7 (4.6, 9.1)	6.7 (4.6, 9.2)
c_{LD}	10.0 (6.6, 14.2)	10.6 (7.2, 14.5)	10.1 (6.6, 14.1)	10.1 (6.5, 14.2)
c_{LM}	5.6 (3.6, 7.9)	5.8 (3.7, 8.4)	5.8 (3.7, 8.0)	5.8 (3.6, 8.0)
c_{LR}	5.2 (3.2, 7.7)	5.6 (3.4, 8.5)	5.1 (3.2, 7.6)	5.2 (3.2, 7.7)

Appendix 2

Posterior–prior plots

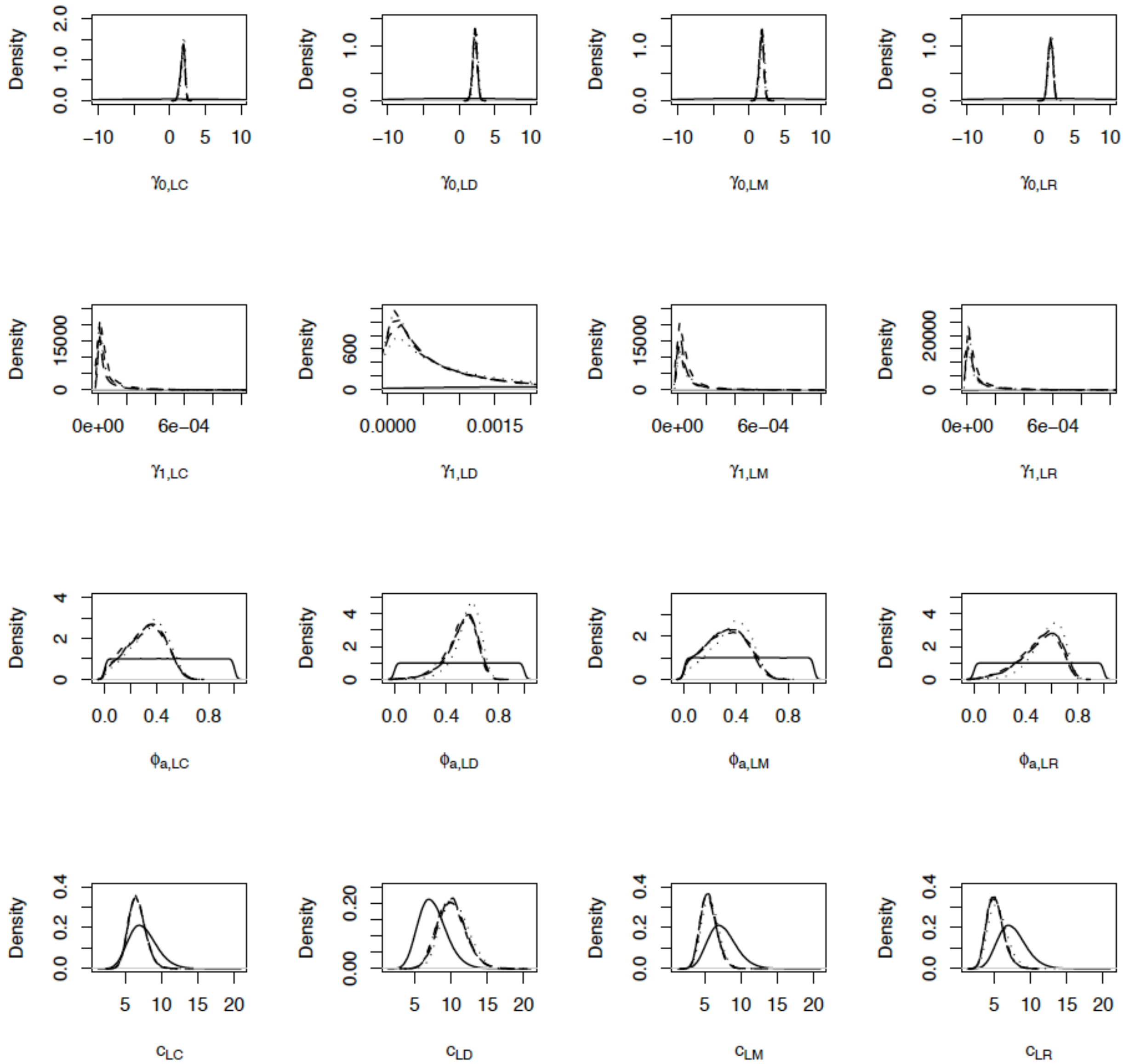

Figure A2.1. Plots of the posterior distributions for the beat-specific grouse parameters ($\gamma_0, \gamma_1, \phi_a, c$) for the predation (dash), prediction (dot) and partial (dot-dash) and full (long dash) diversionary feeding scenarios for grouse–harrier population dynamics, compared to each parameter's prior distribution (solid).

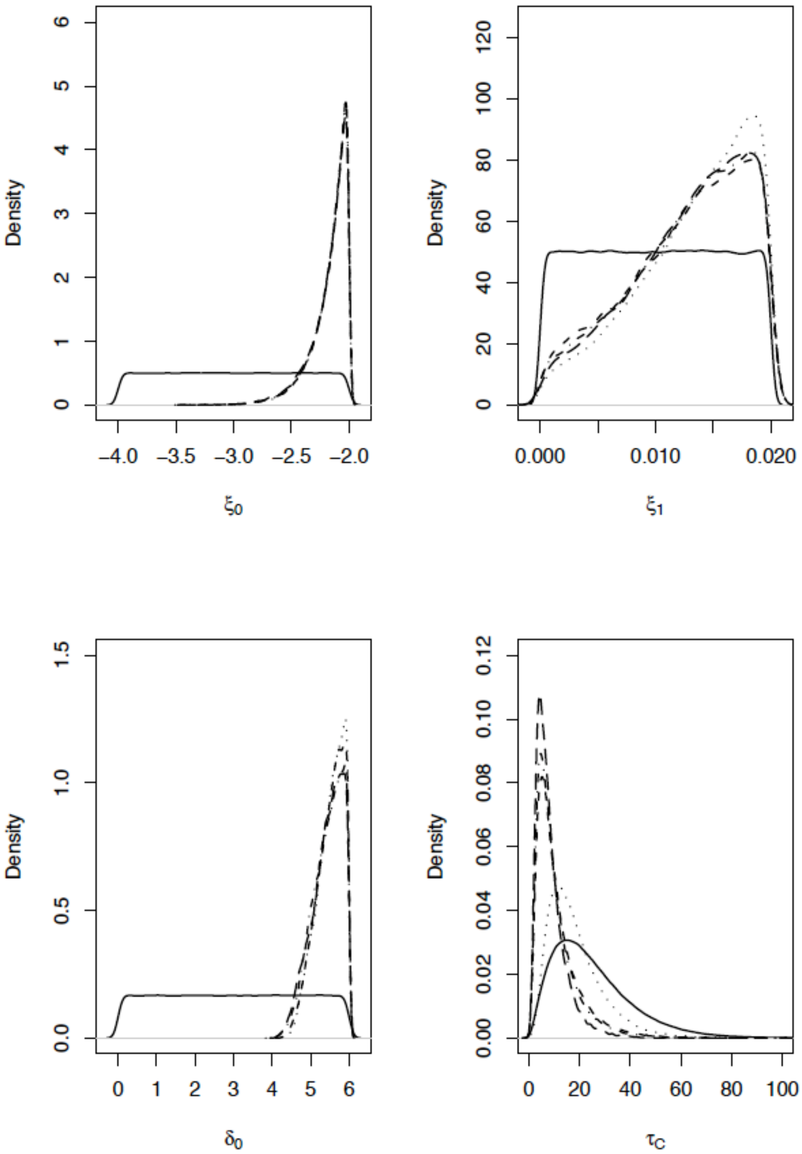

Figure A2.2. Plots of the posterior distributions for the beat-independent grouse parameters ($\xi_0, \xi_1, \xi_2, \tau_c$) for the predation (dash), prediction (dot) and partial (dot-dash) and full (long dash) diversionary feeding scenarios for grouse–harrier population dynamics, compared to each parameter's prior distribution (solid).

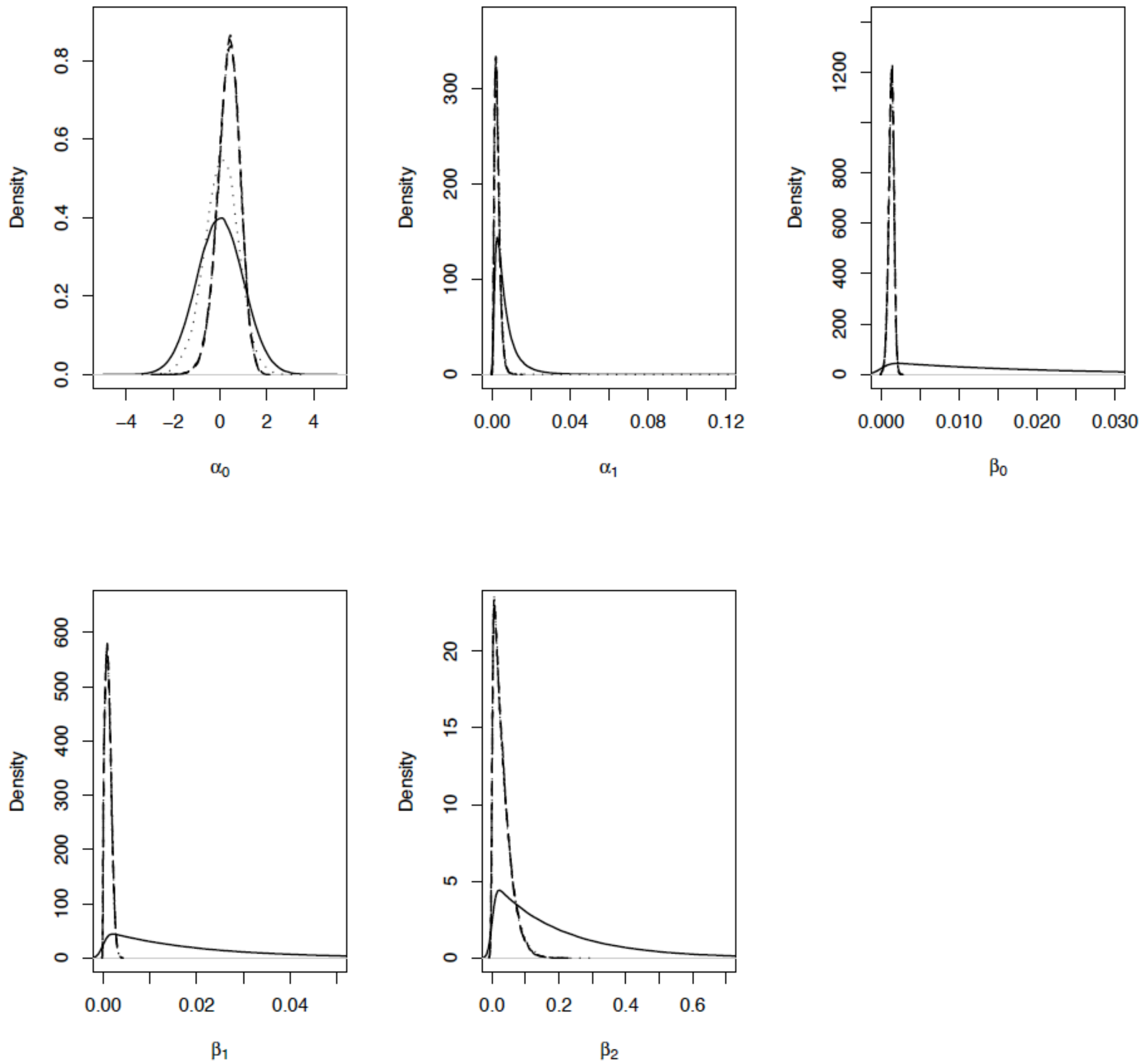

Figure A2.3. Plots of the posterior distributions for the hen harrier parameters ($\alpha_0, \alpha_1, \beta_0, \beta_1, \beta_2$) for the predation (dash), prediction (dot) and partial (dot-dash) and full (long dash) diversionary feeding scenarios for grouse–harrier population dynamics, compared to each parameter's prior distribution (solid).

Appendix 3

Asseburg (2005) Abstract

Multi-species functional response models are required to model the predation of generalist predators, which consume more than one prey species. In chapter 2, a new model for the multi-species functional response is presented. This model can describe generalist predators that exhibit functional responses of Holling type II to some of their prey and of type III to other prey. In chapter 3, I review some of the theoretical distinctions between Bayesian and frequentist statistics and show how Bayesian statistics are particularly wellsuited for the fitting of functional response models because uncertainty can be represented comprehensively. In chapters 4 and 5, the multi-species functional response model is fitted to field data on two generalist predators: the hen harrier *Circus cyaneus* and the harp seal *Phoca groenlandica.* I am not aware of any previous Bayesian model of the multi-species functional response that has been fitted to field data. The hen harrier's functional response fitted in chapter 4 is strongly sigmoidal to the densities of red grouse *Lagopus lagopus scoticus*, but no type III shape was detected in the response to the two main prey species, field vole *Microtus agrestis* and meadow pipit *Anthus pratensis*. The impact of using Bayesian or frequentist models on the resulting functional response is discussed. In chapter 5, no functional response could be fitted to the data on harp seal predation. Possible reasons are discussed, including poor data quality or a lack of relevance of the available data for informing a behavioural functional response model. I conclude with a comparison of the role that functional responses play in behavioural, population and community ecology and emphasise the need for further research into unifying these different approaches to understanding predation with particular reference to predator movement. In an appendix, I evaluate the possibility of using a functional response for inferring the abundances of prey species from performance indicators of generalist predators feeding on these prey. I argue that this approach may be futile in general, because a generalist predator's energy intake does not depend on the density of any single of its prey, so that the possibly unknown densities of all prey need to be taken into account.

Asseburg, C. 2005. Modelling uncertainty in multi-species predator-prey interactions. PhD Thesis, University of St Andrews. URI: http://hdl.handle.net/10023/174.