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Supplementary material

Appendix 1

Table A1. Overview of little owl dead recoveries in the analysis. The table gives all observed EURING codes for recovery circumstances and the conversion into a reduced set of categories of mortality.

EURING code	N	%	EURING description of code	5 categories (Frequency analyses)	3 categories (Model)
			Ring recoveries		
0	16	3.44	Unknown	Unknown	Other
1	162	34.84	Unknown	Unknown	Other
2	8	1.72	Unknown	Unknown	Other
3	12	2.58	Accidentally by man	Human structure	Human
4	9	1.93	Accidentally by human agency	Traffic	Human
5	4	0.86	Unspecified trauma	Various	Other
6	7	1.50	Unspecified predation	Unknown	Other
7	3	0.64	Unspecified natural cause	Unknown	Other
8	4	0.86	Handling casualty	Various	Other
9	3	0.64	Handling casualty	Various	Other
11	1	0.22	Found shot	Various	Other
20	1	0.22	Trapped, hunted or similar	Various	Other
27	15	3.23	Found in nestbox	Various	Other
28	2	0.43	Ring read without recapture	Unknown	Other
32	2	0.43	Caught in human structure	Human structure	Human
33	1	0.22	Entangled in nets	Human structure	Human
35	1	0.22	Electrocution	Various	Other
40	106	22.80	Accidentally by human agency	Traffic	Human
41	9	1.93	Traffic (railway)	Traffic	Human
43	2	0.43	Hit wire or similar	Human structure	Human
44	2	0.43	Hit glass	Human structure	Human
45	11	2.37	Hit massive structure	Human structure	Human
46	28	6.02	Entered building	Human structure	Human
48	1	0.22	Other casualty with human structure	Human structure	Human
49	15	3.23	Drowned in water container	Human structure	Human
50	7	1.50	Other	Various	Other
60	1	0.22	Taken by unspecified animal	Predation	Predation
61	2	0.43	Taken by pet	Predation	Predation
63	9	1.94	Undetermined wild predator	Predation	Predation
65	2	0.43	Predation by bird (owl or raptor)	Predation	Predation
66	1	0.22	Predation by bird	Predation	Predation
67	2	0.43	Taken by conspecific	Various	Other
70	7	1.50	Drowned , other than 49	Human structure	Other
74	1	0.22	Cold weather	Various	Other
76	6	1.29	Poor condition, starvation	Various	Other
78	1	0.22	Weather, unspecified	Various	Other
99	1	0.22	Unknown	Unknown	Unknown
Total	**465**	100			
			Telemetry data		
	11	7.05		Traffic	Human
	49	26.92		Predation	Predation
	68	35.26		Predation	Predation
	17	12.18		Predation	Predation
	15	7.69		Unknown	Other
	9	5.77		Various	Other
	2	1.28		Human structure	Human
	3	1.92		Human structure	Human
	3	1.92		Various	Other
Total	**177**	100			

Table A2: Data array representing the recoveries by year of ringing, year of recovery and cause of death. N_i is the number of ringed Little owls in year i. $R_{i,j}$ is the number of recoveries in the specific year and with the specific cause of death indicated by index j. The array with the recovery data is a 55 x ((55*3+1) = 166) matrix.

Release occasion	Number released	Recovery occasion 1958 $v = 1$			...			Recovery occasion 2012 $v = 55$			never recovered
		predation $k = 1$	human $k = 2$	other $k = 3$	...			predation $k = 1$	human $k = 2$	other $k = 3$	
1957	N_1	$R_{1,1}$	$R_{1,2}$	$R_{1,3}$	$R_{1,j}$	$R_{1,j+1}$	$R_{1,j+2}$	$R_{1,163}$	$R_{1,164}$	$R_{1,165}$	$N_1 - \sum_{j=1}^{165} R_{1,j}$
...	N_i	0	0	0	$R_{i,j}$	$R_{i,j+1}$	$R_{i,j+2}$	$R_{i,163}$	$R_{i,164}$	$R_{i,165}$	$N_i - \sum_{j=1}^{165} R_{i,j}$
2011	N_{55}	0	0	0	0	0	0	$R_{55,163}$	$R_{55,164}$	$R_{55,165}$	$N_1 - \sum_{j=1}^{165} R_{55,j}$

BUGS code of the multi-state mark-recovery model and diagnostics of the model fitting via Markov chain Monte Carlo

Data

nmortcauses number of death causes

nj number of recovery years

ni number of release years

mjuv[ni, 1:(nmortcauses*nj+1)]: number of recoveries per year and death cause. The last column contains the number of individuals never found.

mad[ni, 1:(nmortcauses*nj+1)]: number of recoveries per year and death cause. The last column contains the number of individuals never found.

nringedjuv number of ringed and released juveniles per year

nringedad number of ringed and released adults per year

focc period of recovery within which lambda stays constant

nfocc number of periods "focc"

BUGS Code

```
model{
# define the priors
 Sad  ~ dbeta(1,1)                 # adult annual survival probability
 Sjuv ~ dbeta(1,1)                 # juvenile annual survival probability
  for(k in 1:nmortcauses){
  r[k] ~ dbeta(1,1)                # recovery probability by cause of death
  for(j in 1:nfocc){
    lambdaad0[j,k] ~ dbeta(1,1) # unscaled proportion of death cause k in year j for adults
    lambdajuv0[j,k] ~ dbeta(1,1) # unscaled proportion of death cause k in year j for juveniles
    lambdaad[j,k] <- lambdaad0[j,k]/sum(lambdaad0[j,1:nmortcauses])
    lambdajuv[j,k] <- lambdajuv0[j,k]/sum(lambdajuv0[j,1:nmortcauses])
  }
 }
# define the cell probabilities
# diagonal
for (i in 1:ni){
  for(k in 1:nmortcauses){
    pad[i, (i-1)*nmortcauses+k] <- (1-Sad)*lambdaad[focc[i],k]*r[k]
    pjuv[i, (i-1)*nmortcauses+k] <- (1-Sjuv)*lambdajuv[focc[i],k]*r[k]
  }
```

```
# last column: probability of non-recovery
pad[i, nmortcauses*nj+1] <- 1-sum(pad[i, 1:(nmortcauses*nj)])
pjuv[i, nmortcauses*nj+1] <- 1-sum(pjuv[i, 1:(nmortcauses*nj)])
}

# upper diagonal
for (i in 1:(ni-1)){
 for(j in (i+1):nj){
  for(k in 1:nmortcauses){
   pad[i, (j-1)*nmortcauses+k] <- pow(Sad, (j-i))*(1-Sad)*lambdaad[focc[j],k]*r[k]
   pjuv[i, (j-1)*nmortcauses+k] <- Sjuv*pow(Sad, (j-i))*(1-Sad)*lambdaad[focc[j],k]*r[k]
  }
 }
}
# lower diagonal
for (i in 2:ni){
 for(j in 1:(i-1)){
  for(k in 1:nmortcauses){
   pad[i, (j-1)*nmortcauses+k] <- 0
   pjuv[i, (j-1)*nmortcauses+k] <- 0
  }
 }
}
# define the likelihood
for (i in 1:ni){
  mad[i,1:(nmortcauses*nj+1)] ~ dmulti(pad[i, ], nringedad[i])
  mjuv[i,1:(nmortcauses*nj+1)] ~ dmulti(pjuv[i, ], nringedjuv[i])
}
}
```

Diagnostics of Markov chains (assessment of convergence)

We simulated 2 chains each of length 10000. The first 1000 simulations of each chain were discarded and of the remaining we saved every 3rd simulation. This resulted in 8000 values used for the description of the joint posterior distribution of the model parameters. The minimum number of effective samples was 1200 for the proportion of predation among dead juveniles in year 1964. The 25% quantile of the number of effective samples was 5725 and the median 8000.

All R-hat values (Brooks & Gelman 1998) were smaller than 1.006.

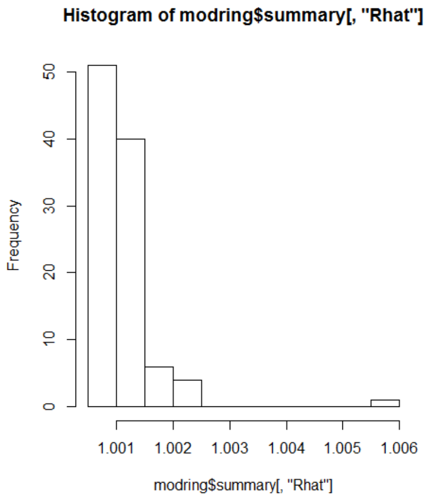
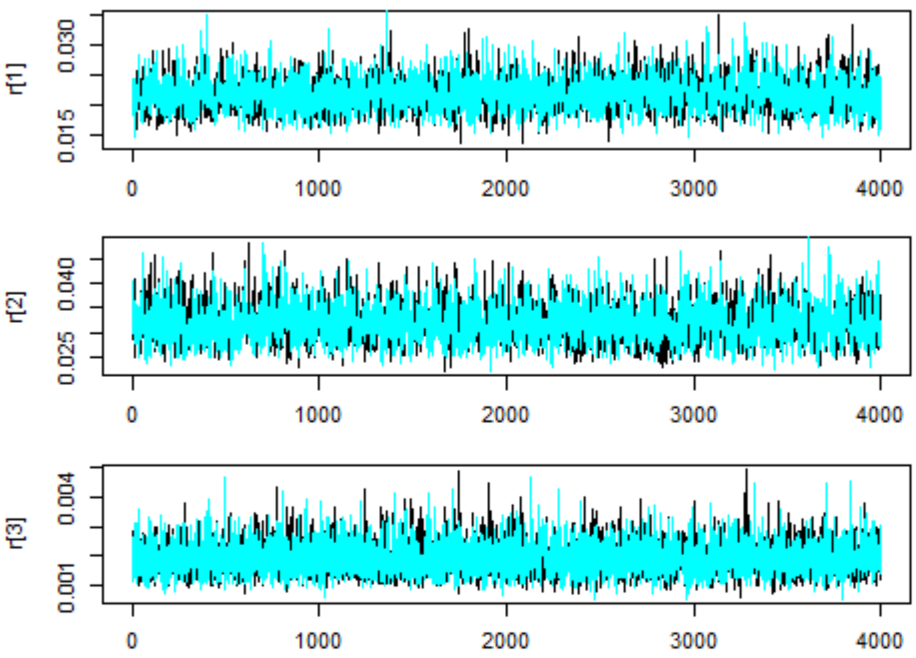


Fig. R-hat values of the 101 model parameters.

We did not find any indication of non-convergence.



Based on the effective sample sizes, the R-hat values and the visual inspection of the Markov chain, we did not find any indication of non-convergence.

References

Brooks, S., and A. Gelman. 1998. General Methods for Monitoring Convergence of Iterative Simulations. Journal of Computational Graphical Statistics **7**:434-455.