Oikos OIK-01810

Russell, D. J. F., McClintock, B. T., Matthiopoulos, J., Thompson, P. M., Thompson, D., Hammond, P. S., Jones, E. L., MacKenzie, M. L., Moss, S. and McConnell, B. J. 2015. Intrinsic and extrinsic drivers of activity budgets in sympatric grey and harbour seals. – Oikos doi: 10.1111/oik.01810

Appendix 1

State assignment

Following McClintock et al. (2013) we assume $\left[s_t \mid \boldsymbol{a},\boldsymbol{b},z_t = i\right] \sim \text{Weibull}(a_i,b_i)$:

$$f\left(s_t \mid \boldsymbol{a},\boldsymbol{b},z_t = i\right) = \frac{b_i}{a_i}\left(\frac{s_t}{a_i}\right)^{b_i-1} \exp\left[-\left(s_t / a_i\right)^{b_i}\right]$$

for state-specific scale parameter $a_i > 0$, shape parameter $b_i > 0$, and $i \in \left\{R,F,T\right\}$.

We also assume $\left[\phi_t \mid \boldsymbol{\upsilon},z_t = i\right]$: $\text{wCauchy}\left(\phi_{t-1},\upsilon_i\right)$:

$$f\left(\phi_t \mid \boldsymbol{\rho},z_t = i\right) = \frac{1}{2\pi}\frac{1-\rho_i^2}{1+\rho_i^2-2\rho_i\cos\left(\phi_t-\phi_{t-1}\right)}$$

with bearing $0 \le \phi_t < 2\pi$ and state-specific mean vector length $0 \le \rho_i < 1$. We assume that time steps with $\omega_{d,t} > T_d$ are equally likely to have been the transit or foraging states and incorporate 'memory' into the state transition probabilities (ψ) as a first-order Markov process. Hence, the model for z_t is:

$$z_t \mid \boldsymbol{p}, z_{t-1} = k \sim \text{Categorical}(p_{k,R}, p_{k,F}, p_{k,T})$$

$$p_{k,i} = \frac{\psi_{k,i} f\left(s_t \mid \boldsymbol{a},\boldsymbol{b},z_t = i\right) f\left(\phi_t \mid \boldsymbol{\upsilon},z_t = i\right) h_{i,t}}{\sum_j \psi_{k,j} f\left(s_t \mid \boldsymbol{a},\boldsymbol{b},z_t = j\right) f\left(\phi_t \mid \boldsymbol{\upsilon},z_t = j\right) h_{j,t}}$$

where

$$h_{i,t} = \begin{cases} 1-I\left(\omega_{d,t} > T_d\right) & \text{if } i = R \\ 1-I\left(\omega_{s,t} > T_s\right) & \text{if } i = F \\ 1-I\left(\omega_{s,t} > T_s\right) & \text{if } i = T \end{cases},$$

$$\psi_{k,i} = \Pr(z_t = i \mid z_{t-1} = k),$$

$k \in \{R, F, T\}$, and $I(\omega_t > T)$is an indicator function taking the value one when argument q is true and zero otherwise.

Assuming independence, we therefore have the conditional likelihood:

$$f(\boldsymbol{\phi}, \mathbf{s}, \mathbf{z} \mid \boldsymbol{\theta}) = \prod_{t=1}^{N} f(\phi_t \mid \boldsymbol{\theta}, z_t) f(s_t \mid \boldsymbol{\theta}, z_t) f(z_t \mid \boldsymbol{\theta}, z_{t-1})$$

where $\boldsymbol{\theta}$ is the set of model parameters.

Whenever intervals are flagged as having no activity data or unreliable locations we ignored the movement data for time step t by setting $f(\phi_t \mid \boldsymbol{\theta}, z_t) f(s_t \mid \boldsymbol{\theta}, z_t) = 1$. Latent state assignments for unreliable or missing time steps were therefore based entirely on the Markov property of the state transition probabilities and were excluded from further analyses.

Appendix 2

Details of telemetry deployments

Table A1. The age and sex of study animals.

	Juvenile		Adult	
	male	female	male	female
Grey seal	24	19	6	14
Harbour seal	13	13	46	54

Table A2. The regional allocation of study animals.

	Northern Scotland		Eastern UK		Western Scotland	Irish Sea
	Northern isles	Moray Firth	Southeastern Scotland	Eastern England		
Grey seal	9		30		19	5
Harbour seal	23	9	30	21	43	0

Appendix 3

Activity budget covariate figures

All results displayed in figures and described here are for the default covariate values (Table A3).

Table A3. The default covariate values used for all results displayed here if that covariate was retained in the model.

<table>
<tr><th rowspan="2">Covariate</th><th>Grey seal</th><th colspan="2">Harbour seal</th></tr>
<tr><th>all state assignments</th><th>other state assignments</th><th>foraging vs travelling</th></tr>
<tr><td>TOD</td><td colspan="3">Interval 1: 00:00 – 06:00</td></tr>
<tr><td>Region</td><td>Eastern UK</td><td>South-Eastern Scotland</td><td>NA</td></tr>
<tr><td>Depth threshold</td><td colspan="2">6m</td><td>2 m</td></tr>
<tr><td>Age</td><td colspan="2">adult</td><td>NA</td></tr>
<tr><td>Sex</td><td colspan="3">female</td></tr>
<tr><td rowspan="2">DOY</td><td colspan="3">Mid DOY</td></tr>
<tr><td>6 August</td><td>20 February</td><td>14 April</td></tr>
</table>

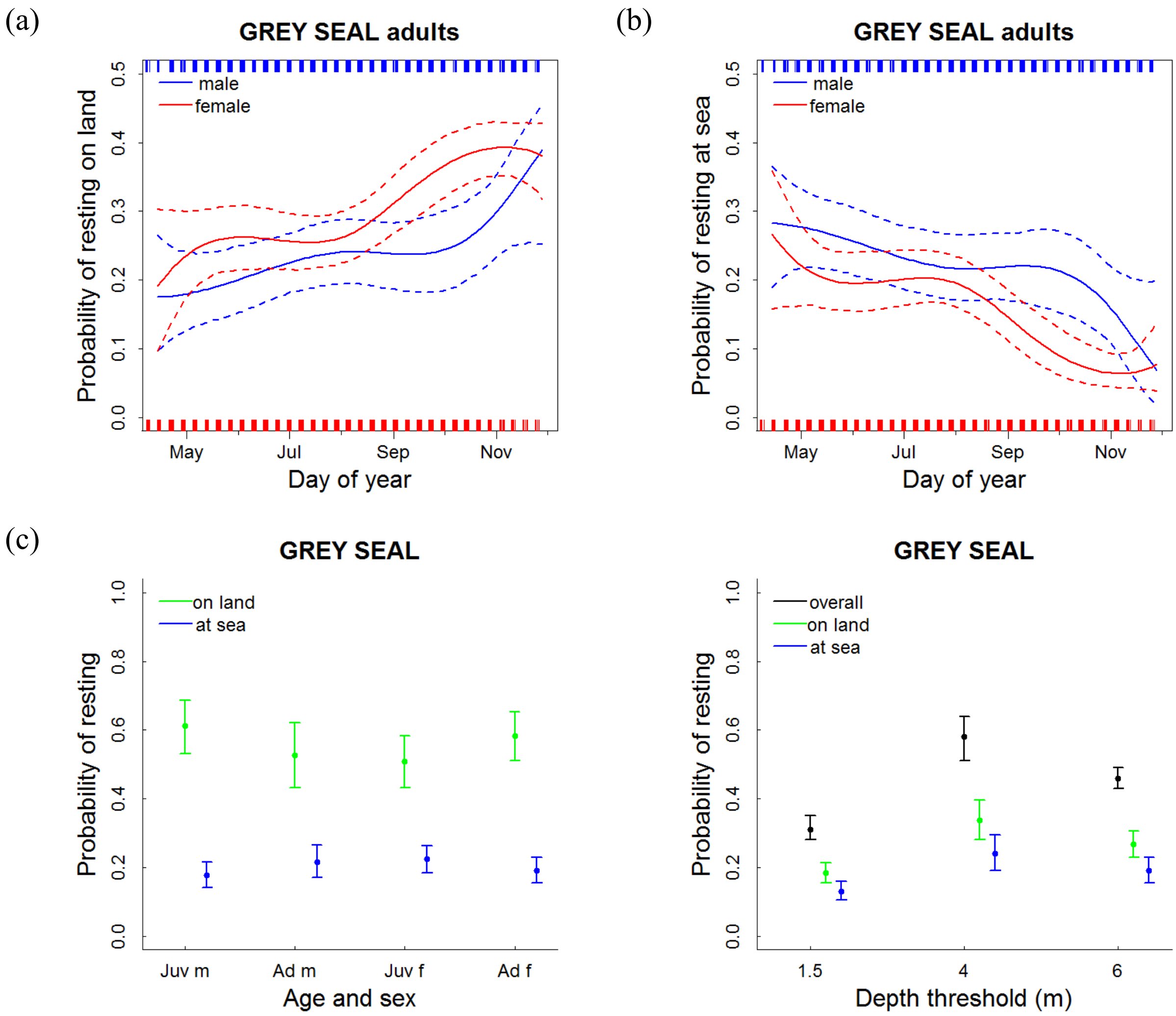

Figure A1. The probability of resting (where indicated) in grey seals (with 95% confidence intervals) by day of year (a and b), age and sex (c), and depth threshold (d). The rug plots (a and b) indicate the presence of data across the range of the covariate.

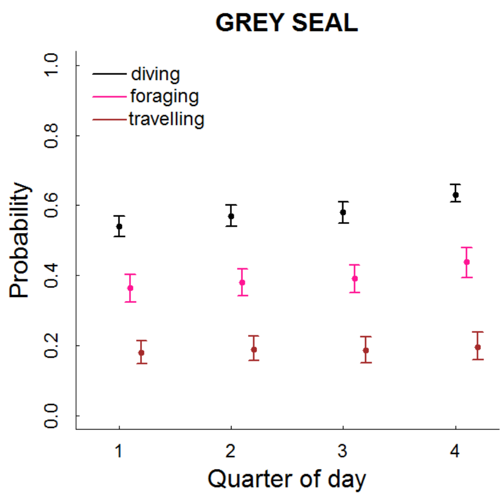

Figure A2. The probability of diving, foraging and travelling in grey seals (with 95% confidence intervals) by time of day.

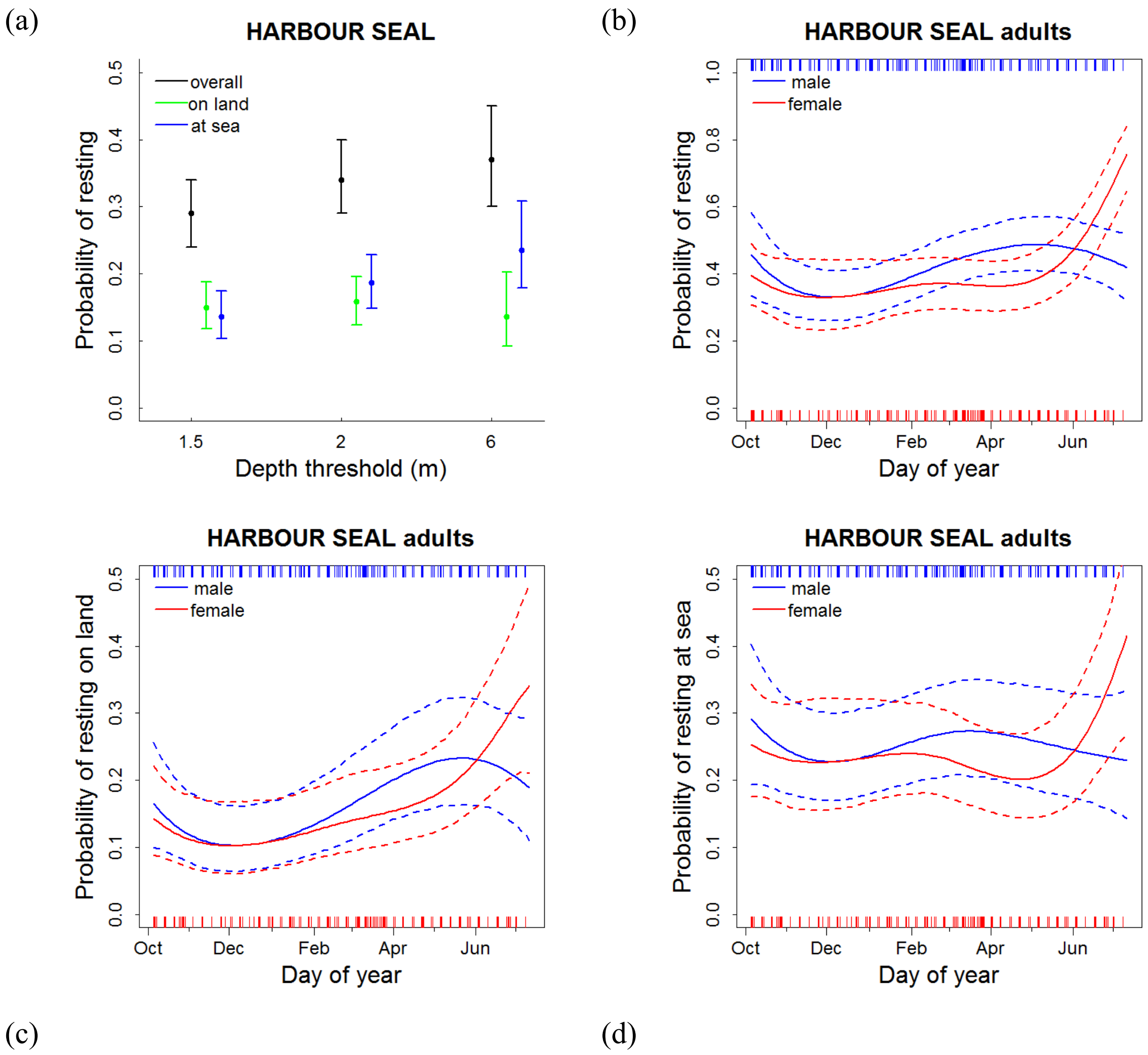

Figure A3. The probability of resting (where indicated) in harbour seals (with 95% confidence intervals) by depth threshold (a) and day of year (b–d). The rug plots (b–d) indicate the presence of data across the range of the covariate.

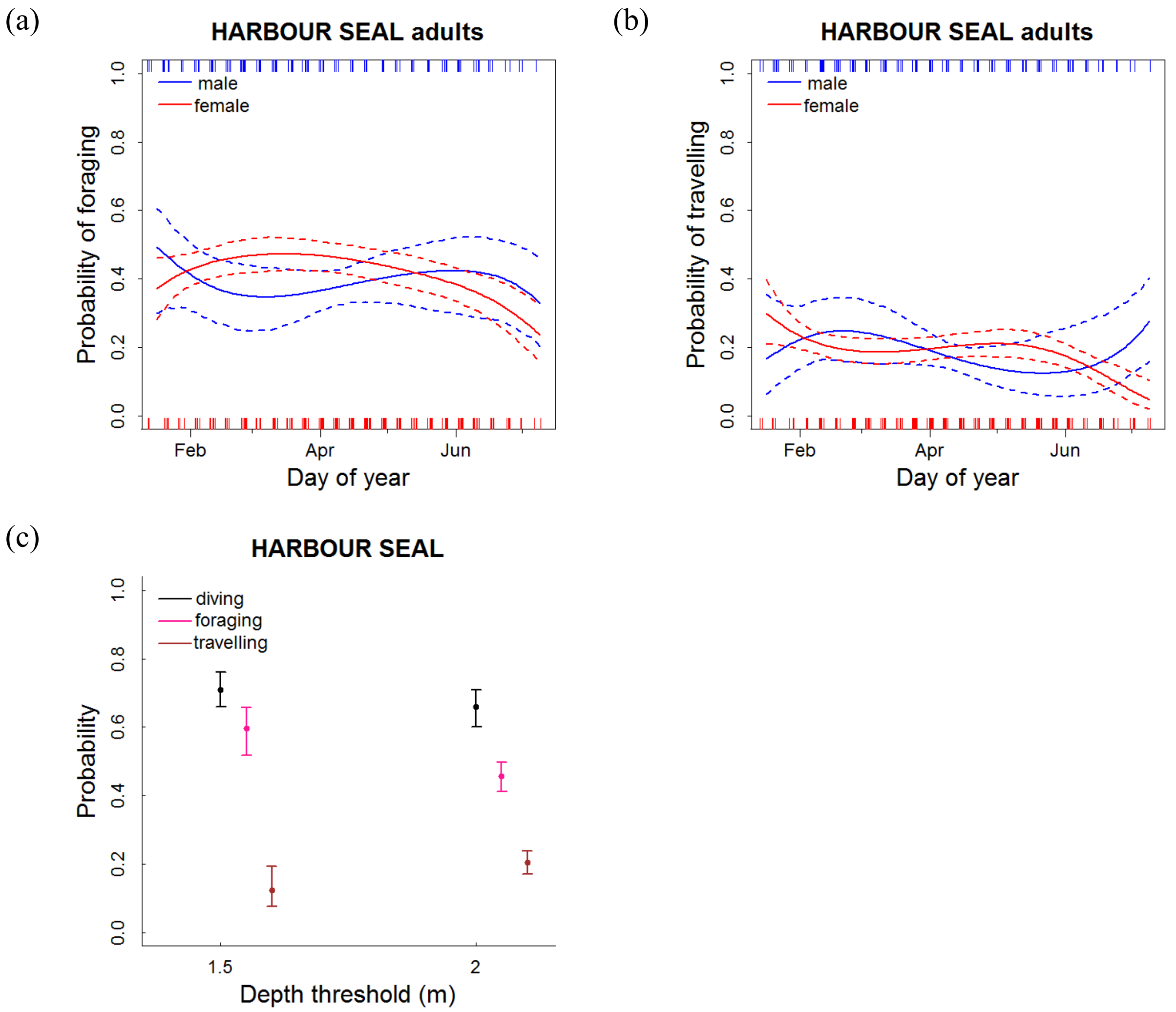

Figure A4. The probability of diving, foraging and travelling in harbour seals (with 95% confidence intervals) by day of year (a and b) and depth threshold (a). The rug plots (a and b) indicate the presence of data across the range of the covariate.