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Designing a camera trap monitoring program to measure efficacy of invasive predator management

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Power analysis using density estimation with the random encounter model (Rowcliffe et al. *2008)*

Rowcliffe *et al.* 2008 describe a random encounter model to estimate animal density with camera trapping. Here, we describe how power analyses can be conducted using density estimation and present the outcomes in Figure S1.

The model we use here has a similar structure to the model described in Eqns 1–4, but then scales the relative trapping index to provide an estimate of density. Note that this adds extra model assumptions and thus introduces further estimation uncertainty. We estimate density using the random encounter model (Rowcliffe *et al. 2008)* as follows:

$$\widehat{D}_s = \hat{\mu}_s \frac{\pi}{vr(2+\theta)} \quad \text{(S1)}$$

where $\widehat{D}_s$ = density, $\hat{\mu}_s$ = mean trapping rate (photos/month), v = average animal speed of movement (km/month), and the sector-shaped detection zone of the camera consisting of r = detection distance (between animal and camera, km) and θ = detection arc (radians). Density estimates $\widehat{D}_1$ and $\widehat{D}_2$ can be used to estimate the difference in density between unbaited and baited sites. Animal speed of movement v, detection distance r and detection arc θ are modelled with variation:

$$v \sim N(\mu_v, \sigma_v^2) \quad \text{(S2)}$$

and

$$r \sim N(\mu_r, \sigma_r^2) \quad \text{(S3)}$$

and

$$\theta \sim N(\mu_\theta, \sigma_\theta^2) \quad \text{(S4)}$$

We set μ_v = 282 km/month with σ_v = 111 km/month (Carter *et al.* 2012), μ_r = 0.0076 km with σ_r = 0.0011 km, and μ_θ = 0.33 radians with σ_θ = 0.16 radians (Van Hespen 2015).

We simulated the same scenarios as in Figure 1 of this paper and used power analyses with density estimation (Eqns S1–4). Results are shown in Fig. S1.

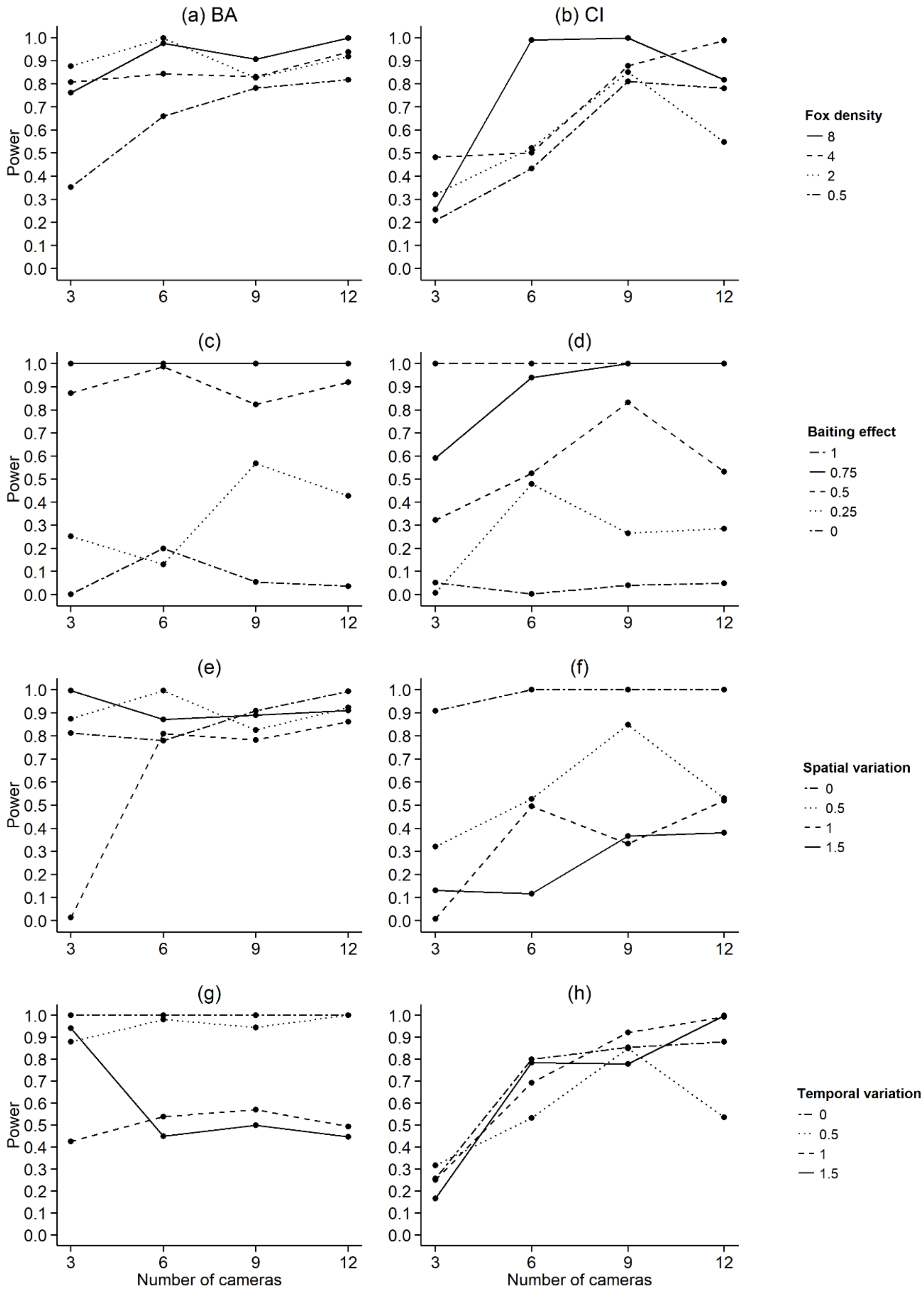

Fig. S1. Power analyses with the model described in Eqns S1–S4 for (a, b) four different pre-baiting fox densities, (c, d) five different baiting intensities, (e. f) four different levels of spatial variation and (g, h) four different levels of temporal variation, each for before/after (a, c, e, g) and control impact (b, d, f, h) sampling design. We set μ_v = 282 km/month with σ_v = 111 km/month (Carter *et al.* 2012), μ_r = 0.0076 km with σ_r = 0.0011 km, and μ_θ = 0.33 radians with σ_θ = 0.16 radians (Van Hespen 2015). Further parameter values, if not displayed in the legend, are as in Table 1.

BA, CI and BACI sampling design

Power analysis can also be conducted to plan a BACI design. It is important to keep in mind that BACI design uses twice the number of cameras as a BA design, and twice the number of monitoring months as a CI design (Figure S2). To compare the power of a monitoring study with a BACI design to a study with a BA or CI sampling design, the data for a BACI design must either be simulated using only half the number of cameras per site if comparing to a BA sampling design or only half the monitoring months per year if comparing to CI sampling design.

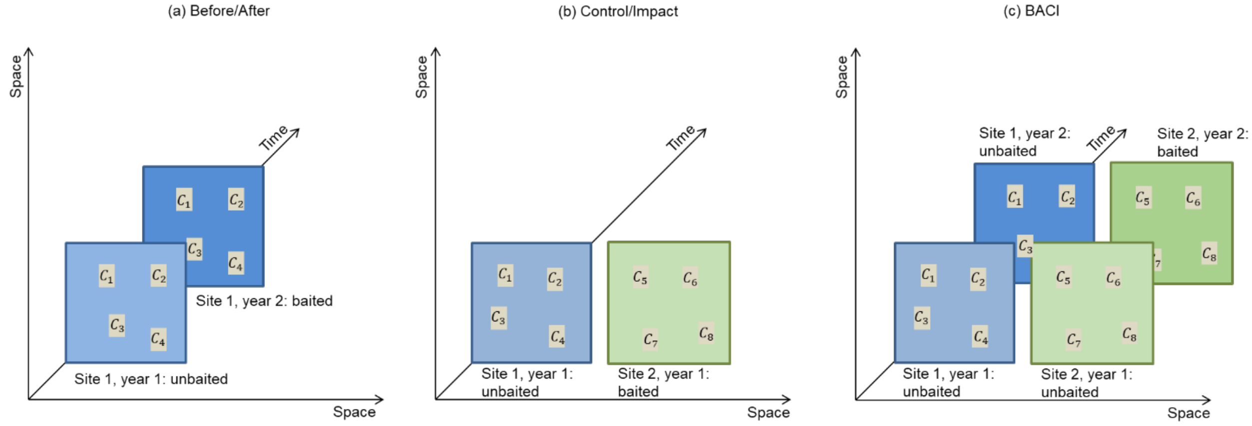

Fig. S2. Overview of (a) before/after and (b) control/impact and (c) BACI sampling design. C_n indicates camera number n, with the same cameras used in the same location in the before/after design, and different cameras used in the two sites of the control/impact design. The before/after design is paired in space and differs in time, whereas the control/impact design is paired in time and differs in space.

Trapping rates, spatial and temporal variation in pilot study

Levels of spatial and temporal heterogeneity are estimated using data collected in a pilot study (Benshemesh *et al.* 2014) that was conducted in preparation for the nationwide monitoring study for malleefowl conservation (Benshemesh *et al.* 2016). The data were collected in Wandown Nature Reserve, Victoria, Australia (34°48'24.7"S, 142°59'48.6"E), from June 1, to October 31, 2013. The reserve is a 20 km^2 remnant patch of mallee vegetation surrounded by agricultural land. No fox baiting was carried out in the reserve. Sixteen Keepguard (a.k.a. ScoutGuard) KG680v cameras were placed in the reserve, 50 - 100 m off tracks to avoid interference by people, giving a density 0.8 cameras/km^2. Each camera was set to take one 3-megapixel photograph when triggered (Benshemesh*et al.* 2014). Cameras were placed at a height of 50-100 cm from the ground. Keepguard KG680v cameras have a trigger speed of one second, which could not be adjusted. A delay of 5 minutes was simulated in the dataset between each trigger event to reduce repeat detections of the same species, and sensor sensitivity was set at normal. The detection zone A of the Keepguard KG 680v was measured following the methods described in Van Hespen (2015), and found to be $\hat{r} = 7.6$ m and $\hat{\theta} = 0.33$ radians.

We used the model described in Eqns 1–4 to estimate the mean trapping rate, spatial and spatial heterogeneity in the pilot data, and estimated the following values: $\hat{\mu} = 6$ (sd = 1.57), $\widehat{\sigma_t} = 0.4$ (sd = 0.24) and $\widehat{\sigma_c} = 0.73$ (sd = 0.16).

We assumed that fox density in the pilot study was 4 foxes/km^2 and speed was 9.4 km/day, and then simulated a trapping rate with Eqn 5. We then compared this simulated rate to the trapping rate in the pilot data to check if the model in Eqn 5 returned realistic trapping rates (Figure S3).

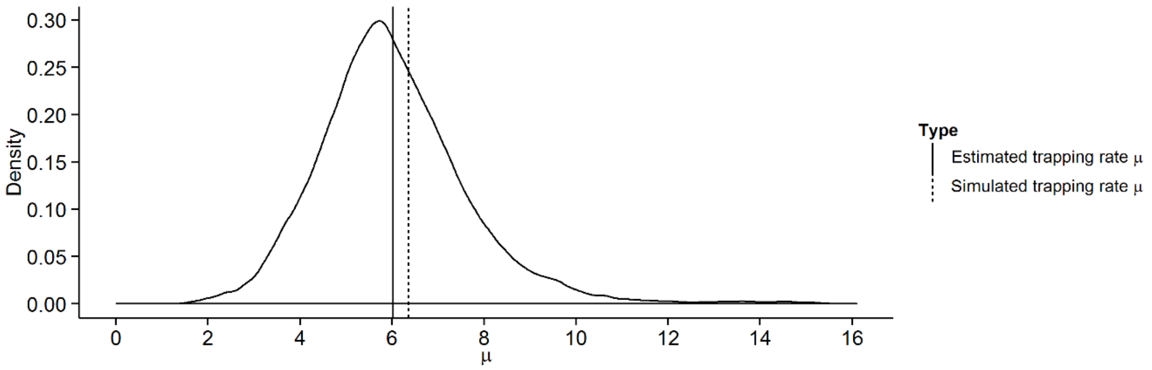

Fig. S3. Simulated trapping rate (dotted line) vs. trapping rate in data collected in pilot study (solid line). We simulated μ according to Eqn 5, and assumed that the fox density in the pilot study was 4 foxes/km^2 and speed was 9.4 km/day. We simulated the same camera trap detection zone as used in the pilot study, a Keepguard KG680v.