Are acoustic spatial capture-recapture models also robust to misspecified detection functions?

David K. E. Chan[1,2], Janice Seo[1], and Ben C. Stevenson[2]

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Spatial capture-recapture (SCR)

> A statistical method to infer animal density from spatially indexed capture-recapture data.

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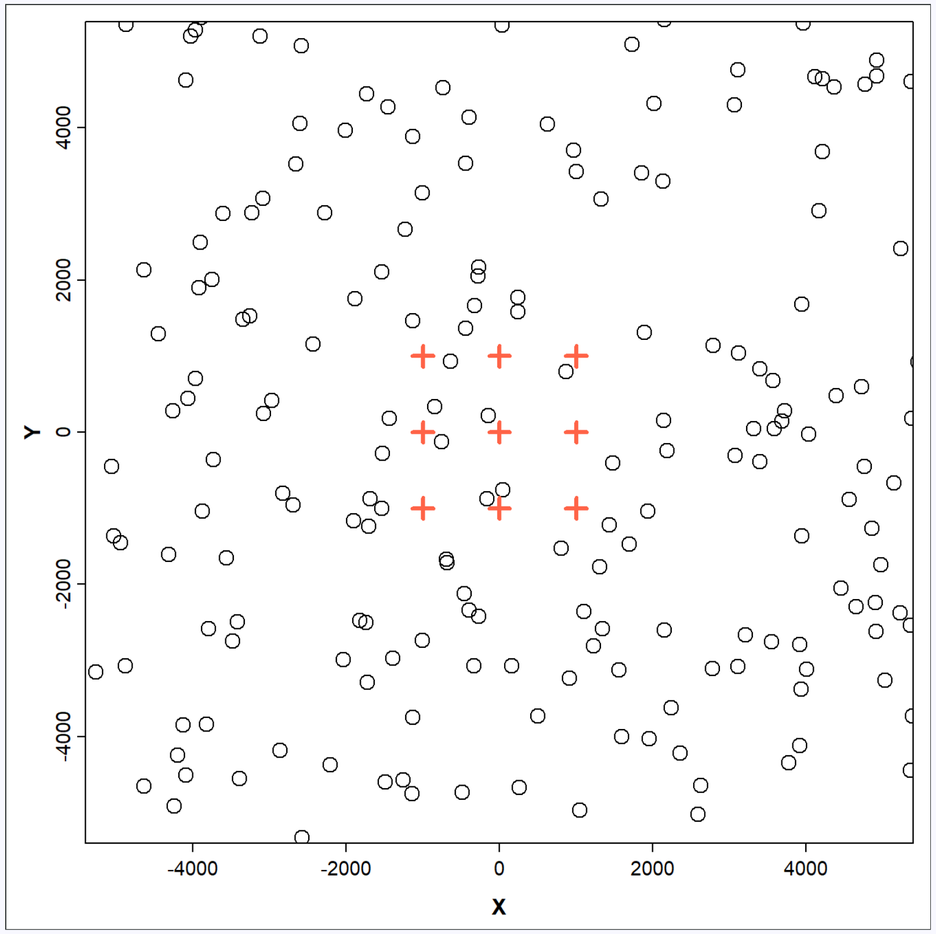
Spatial capture-recapture (SCR)

- The animals' activity centres are a realisation of a Poisson point process.



Let $N \sim \text{Poisson}(Da)$, where D is animal density and a is the "area" of the survey region. The points represent animals' activity centres and are uniformly distributed across the region.

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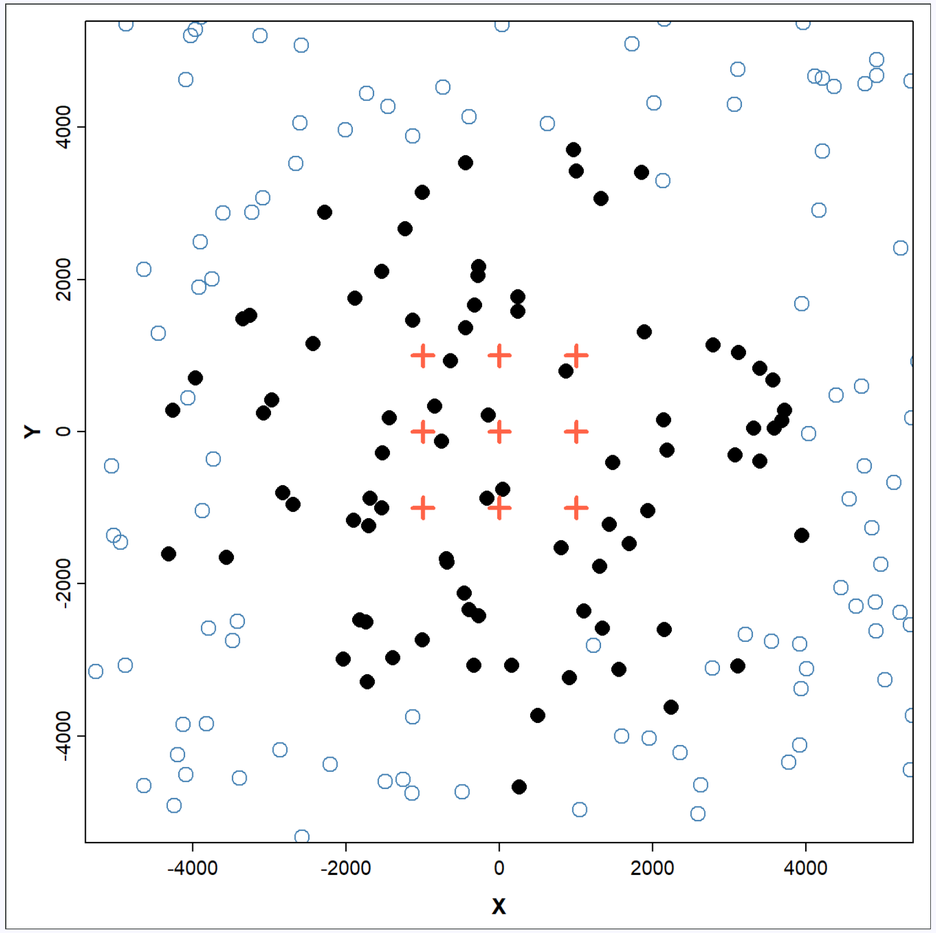

Out of the N animals, n animals were detected and these animals' activity centres are a realisation of a thinned point process.

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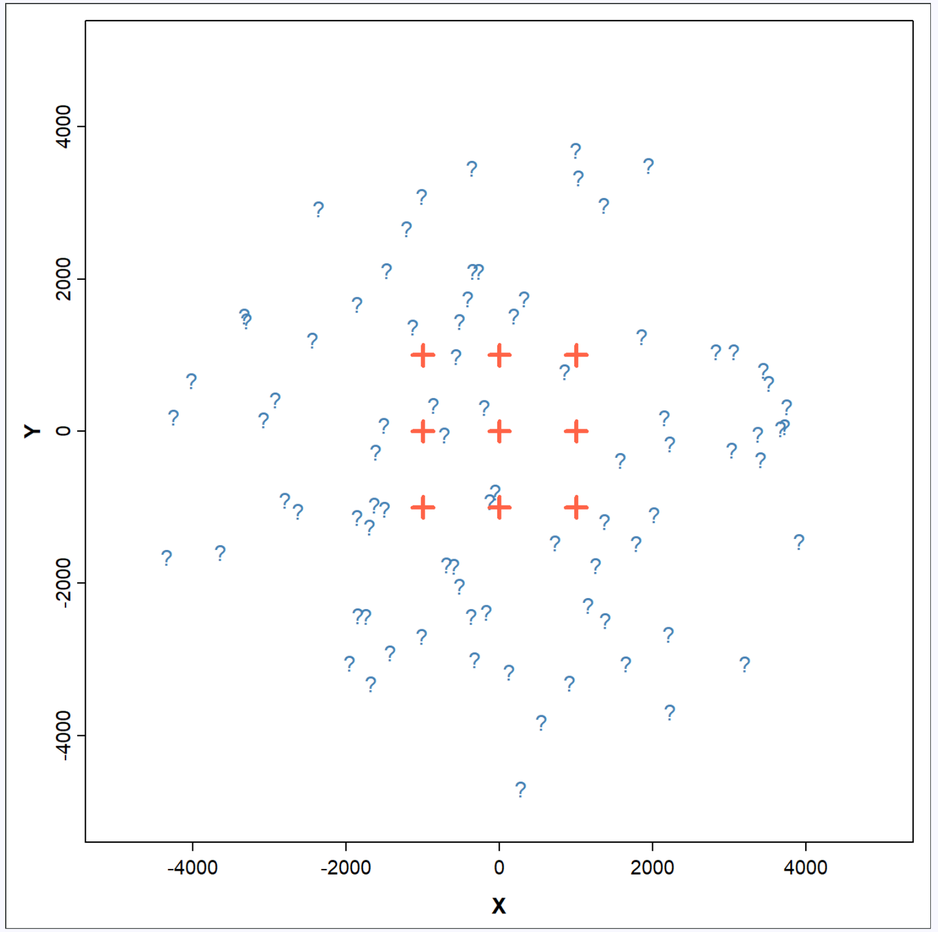

We only explicitly observe the detected animals when they "interact" with the detector.

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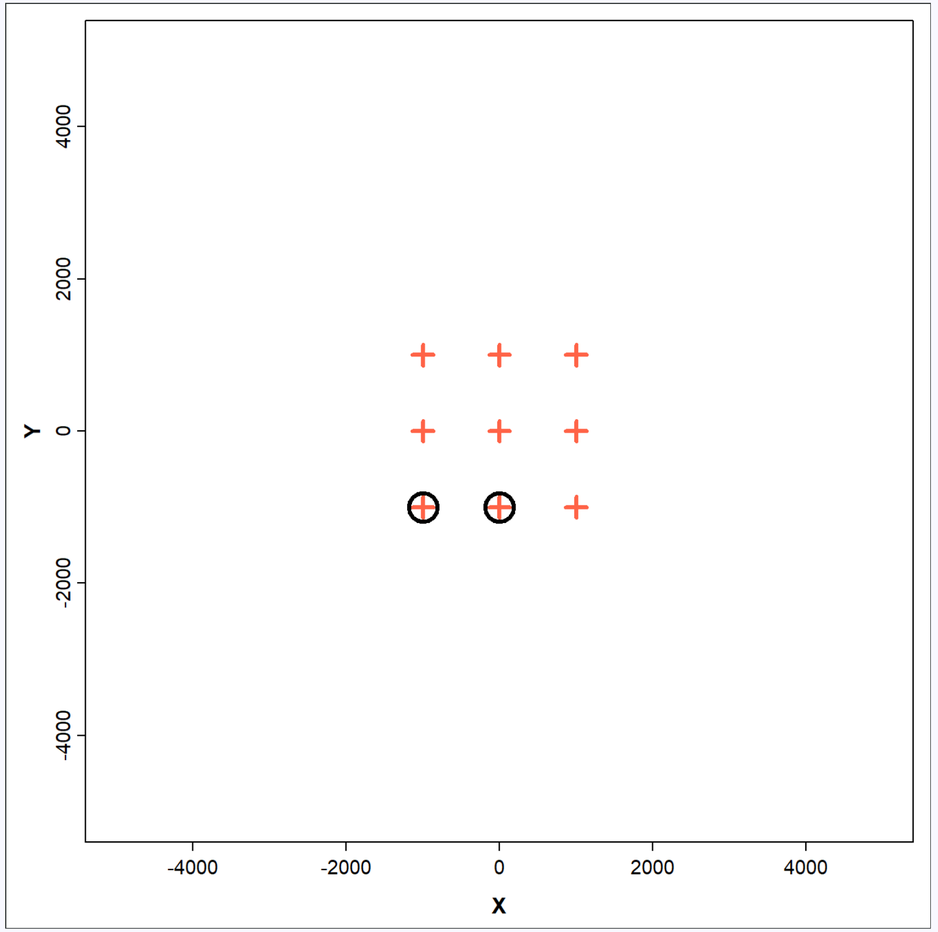

$\omega_1 = (0, 0, 0, 0, 0, 0, 1, 1, 0)$

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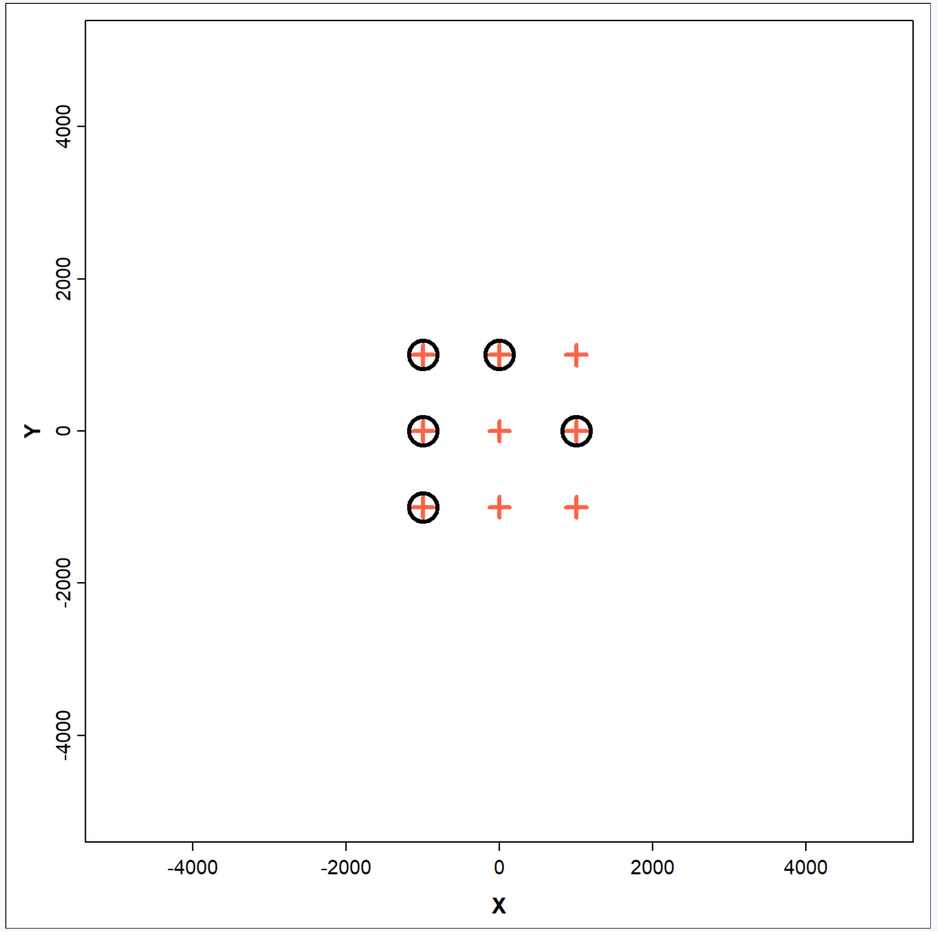

$\omega_2 = (1, 1, 0, 1, 0, 1, 1, 0, 0)$

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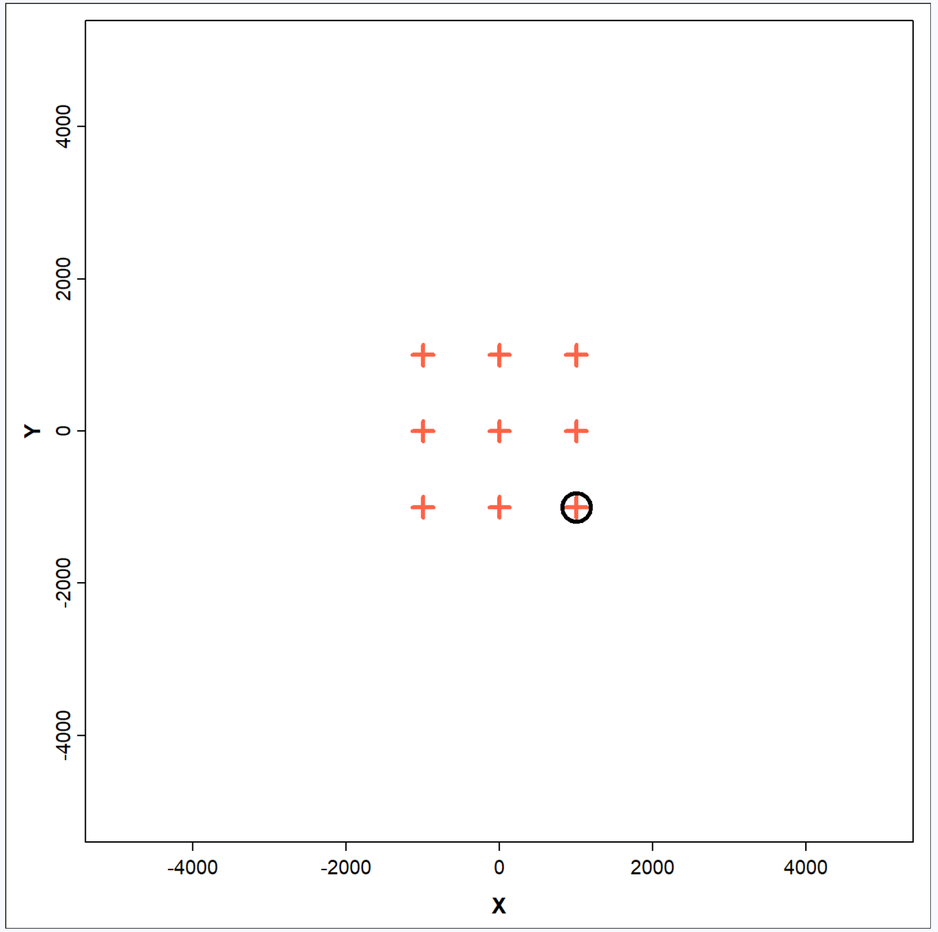

$\omega_3 = (0, 0, 0, 0, 0, 0, 0, 0, 0, 1)$

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- The animals' activity centres are a realisation of a Poisson point process.
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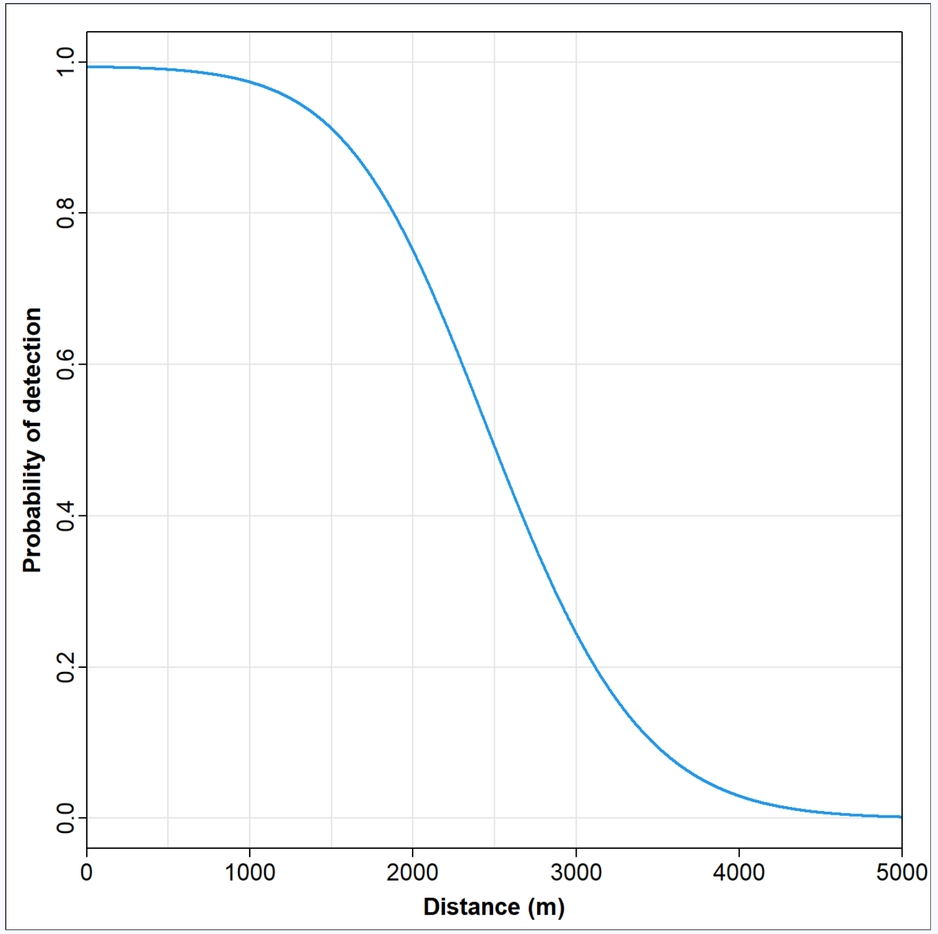
- We can still estimate a detection function with this data and, hence, a detection surface.



Let $g\{d(\boldsymbol{s}_i, \boldsymbol{x}_j); \boldsymbol{\theta}\}$ be the detection function. One example is $g\{d(\boldsymbol{s}_i, \boldsymbol{x}_j); \boldsymbol{\theta}\} = 1 - \exp[-\lambda_0 \exp\{-d(\boldsymbol{s}_i, \boldsymbol{x}_j)^2 / 2\sigma^2\}]$, where $d(\boldsymbol{s}_i, \boldsymbol{x}_j)$ is the distance between an activity centre location $\boldsymbol{x}_i$ and a detector location $\boldsymbol{x}_j$.

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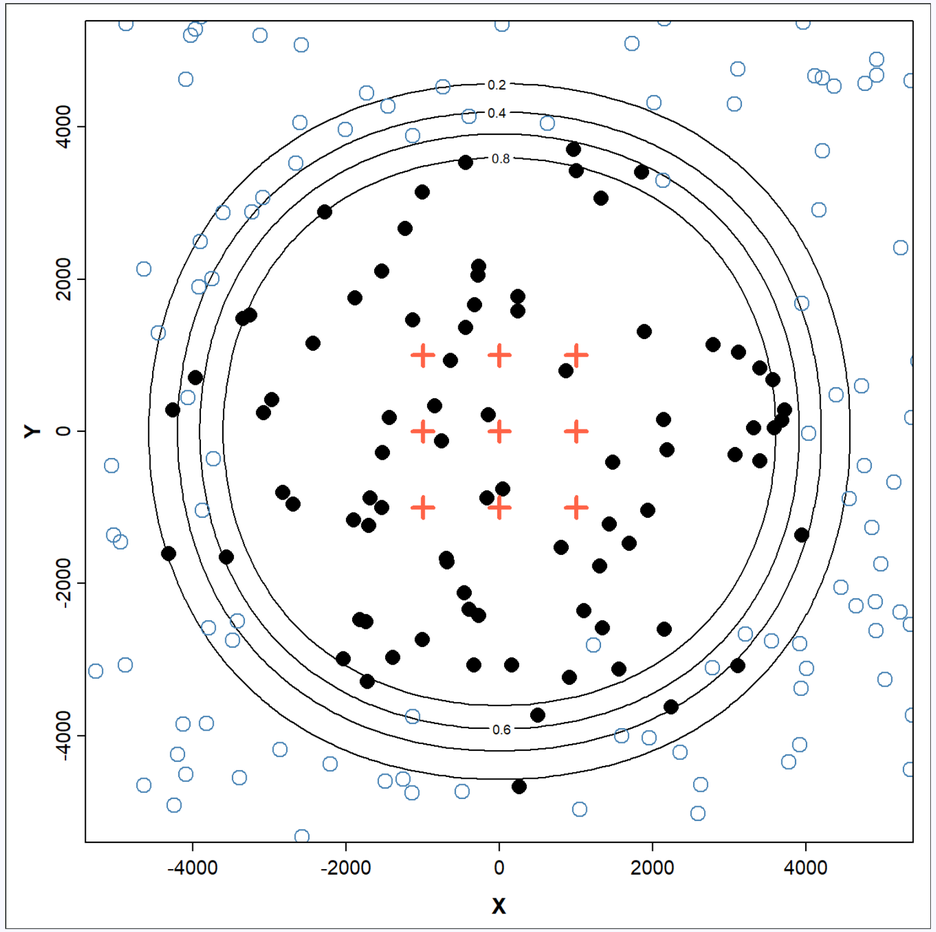

The thinned point process is a realisation of the Poisson point process thinned by the probability of detecting an animal at all, $p(\boldsymbol{s}) = 1 - \prod_{j=1}^{J}[1 - g\{d(\boldsymbol{s}_i, \boldsymbol{x}_j); \boldsymbol{\theta}\}]$.

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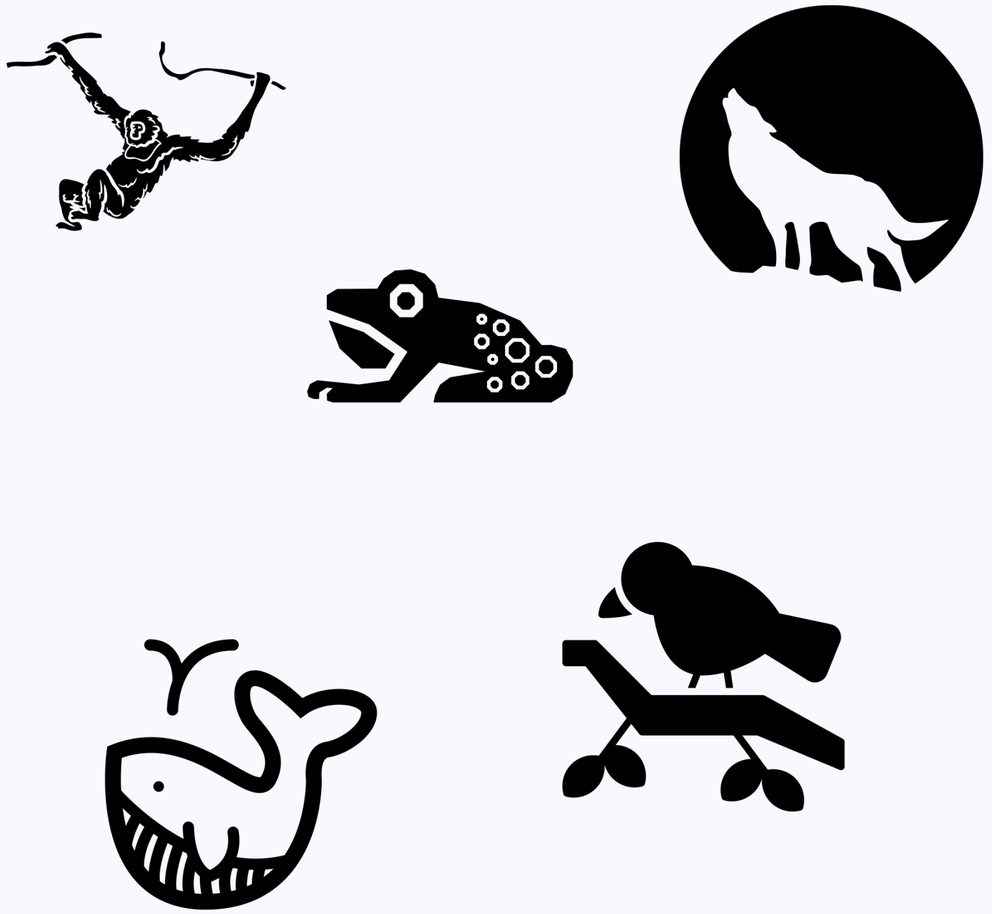

Figure: Example of (cartoon) taxa that we can survey.

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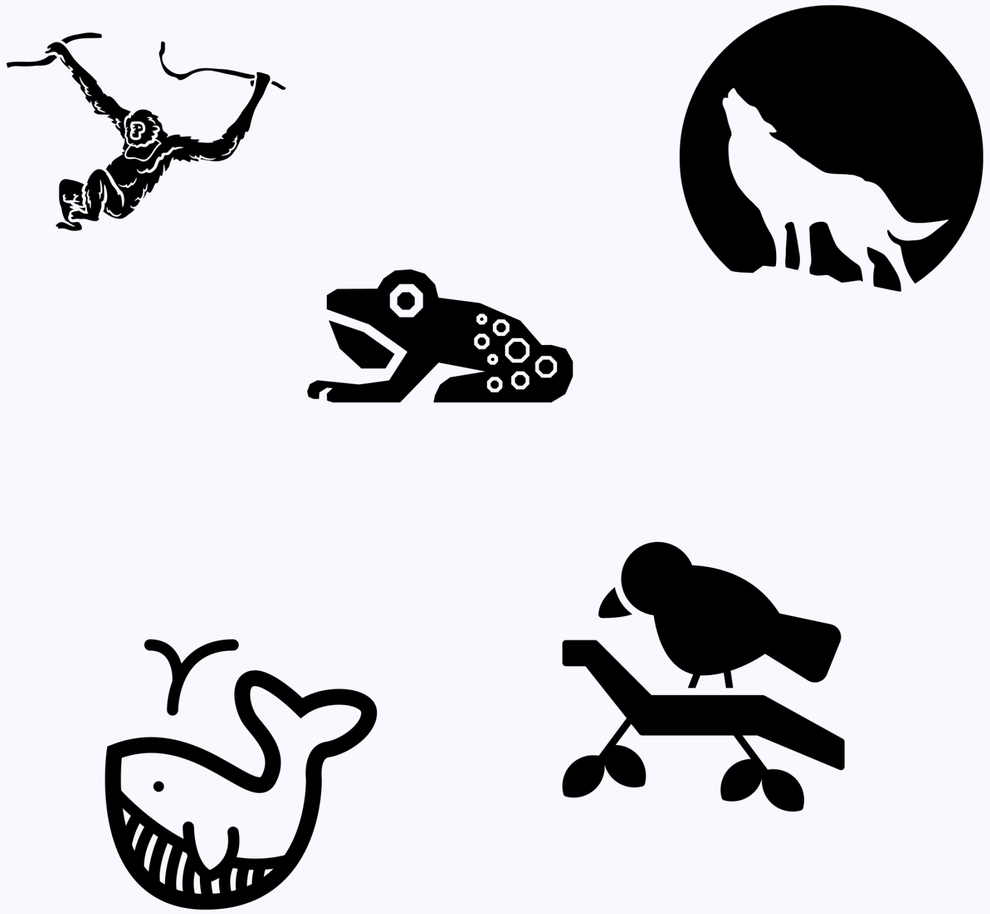
Acoustic surveys

> A survey mode where the target population is detected acoustically.



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Acoustic spatial capture-recapture (ASCR)

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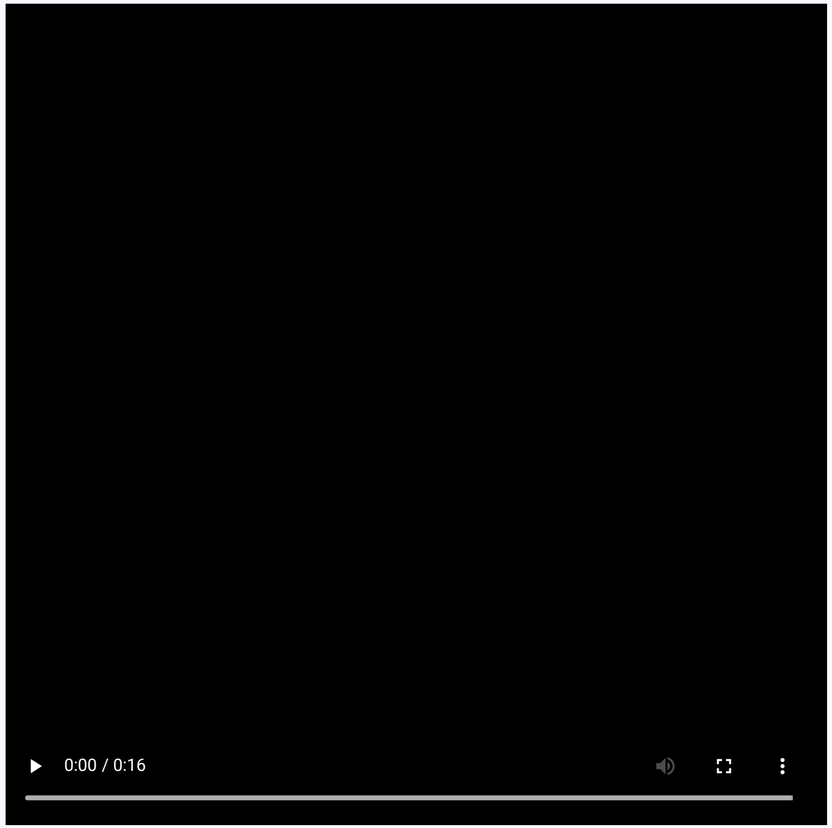

Animation: What a capture-recapture of an animal call looks like.

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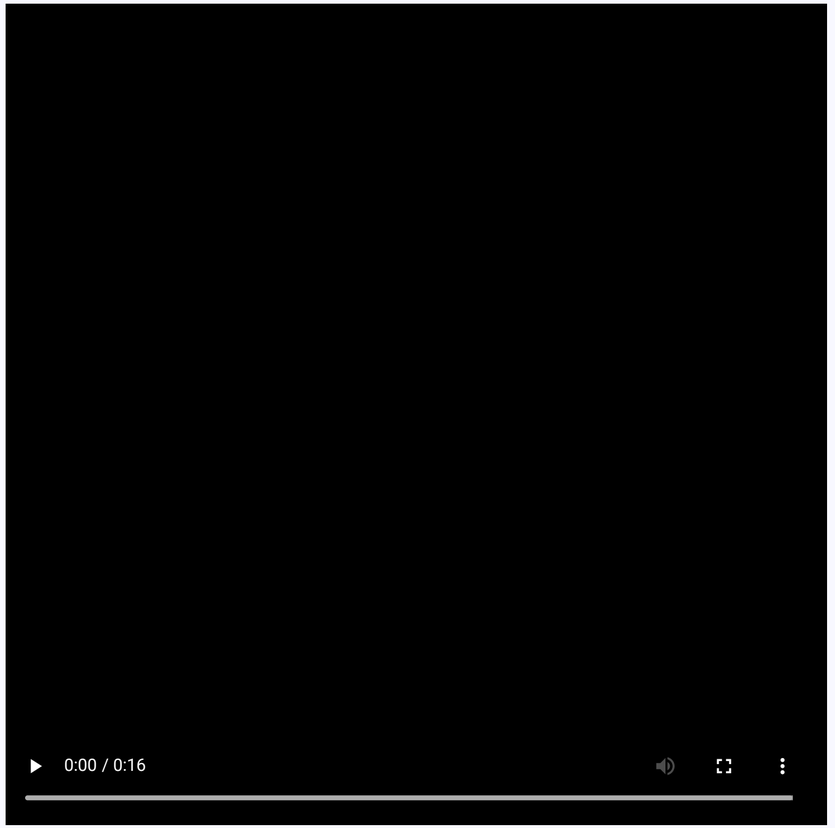

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SCR ⇝ ASCR

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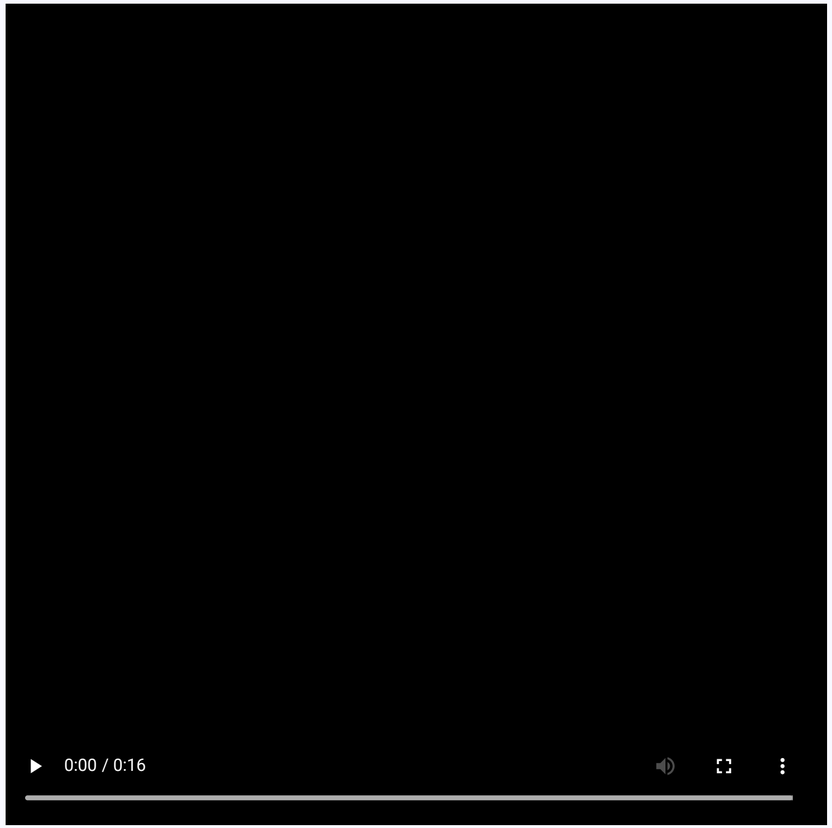
2. The *calling* locations are now a realisation of a Poisson point process.

3. Inference on *call* density and the detection probability of *calls*.



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Is SCR's density estimator robust to detection function misspecification?

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SCR literature on misspecified detection functions

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> Based on our simulation study, we can make recommendations for SCR users regarding the choice of a detection function. First, density and population size estimates are largely immune to misspecifications of the detection function.
>
> — Dey et al. (2022)

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Number (#) of detectors in the literature

SCR Example #1 | SCR Example #2 | ASCR Example #1 | ASCR Example #2

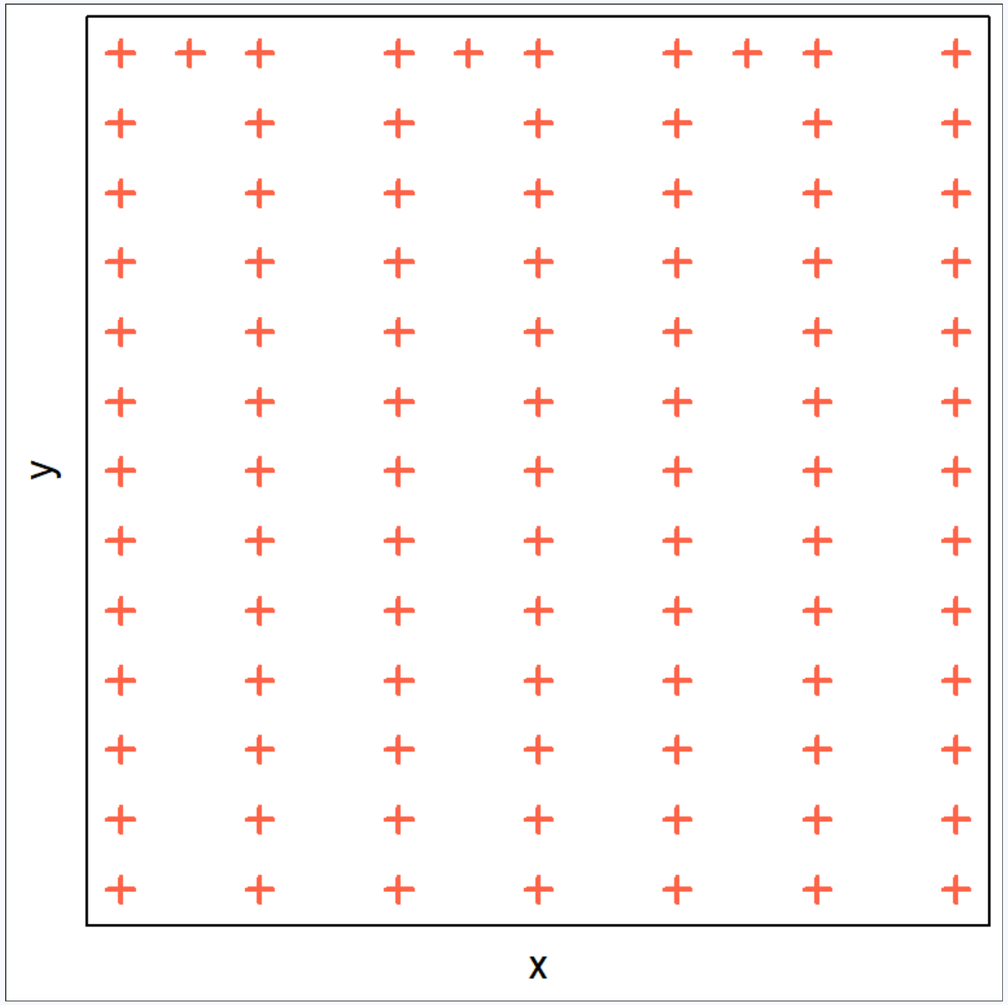

Figure: The 94 detectors used in a SCR survey described by Efford, Borchers, & Byrom (2009).

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Goals of the investigation

1. **Is SCR's density estimator robust to the choice of detection function?**

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2. Does 1. depend on the number *and* spatial configuration of the detectors[1]?

3. Can model selection methods, like AIC, select an "appropriate" detection function?

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Simulation study: Survey designs

We simulate ASCR data for seven survey designs.

Designs 1–3 | Designs 4–6 | Design 7

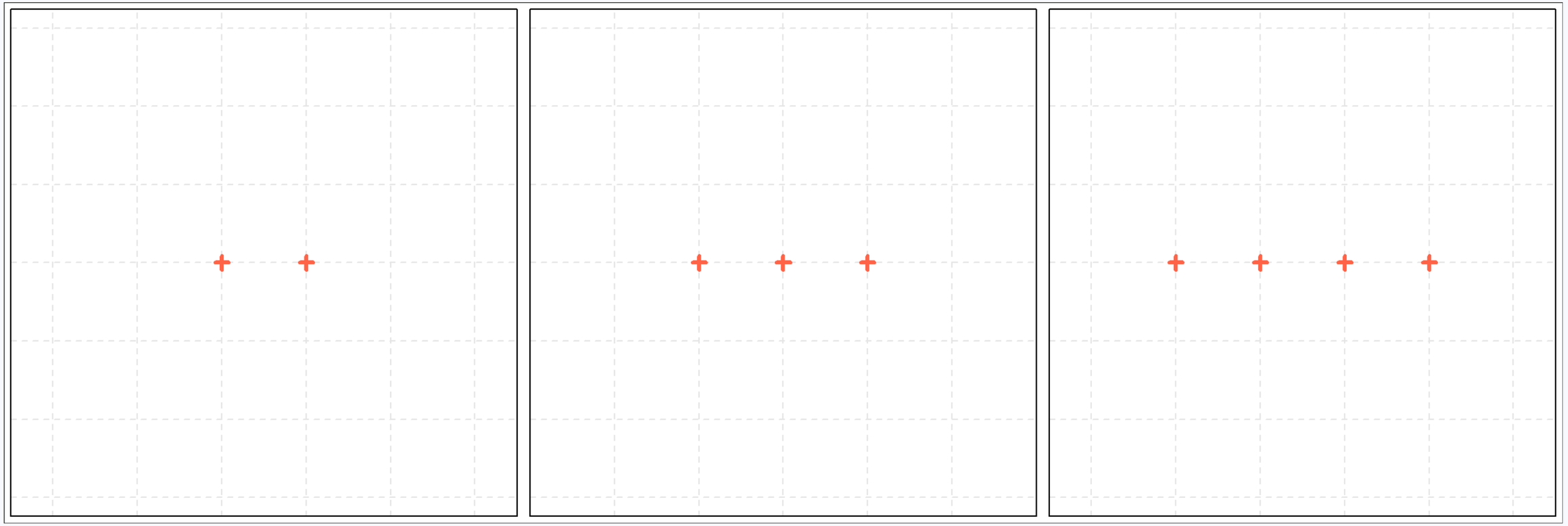

Figure: The first set is linear arrangements based on an acoustic survey of gibbons conducted by Kidney et al. (2015).

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Simulation study: Parameter vector

We use the estimated parameter vector from an ASCR model fitted to one of the acoustic surveys conducted by Measey et al. (2017).

Signal strengths and times of arrival are modelled by conditioning on the observed capture histories.

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- Signal strength

Call density	59.72 calls per hectare per second.
Detection function Signal Strength	β_0 = 158.68 dB. β_1 = −1.81 dB. σ_{ss} = 4.82 dB.
Times of arrival	σ_t = 2.08 ms

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- One of Ben's favourite species to model!

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Simulation study: Fitted detection functions

For each simulated dataset, we fit four different detection functions to answer our primary question of the investigation.

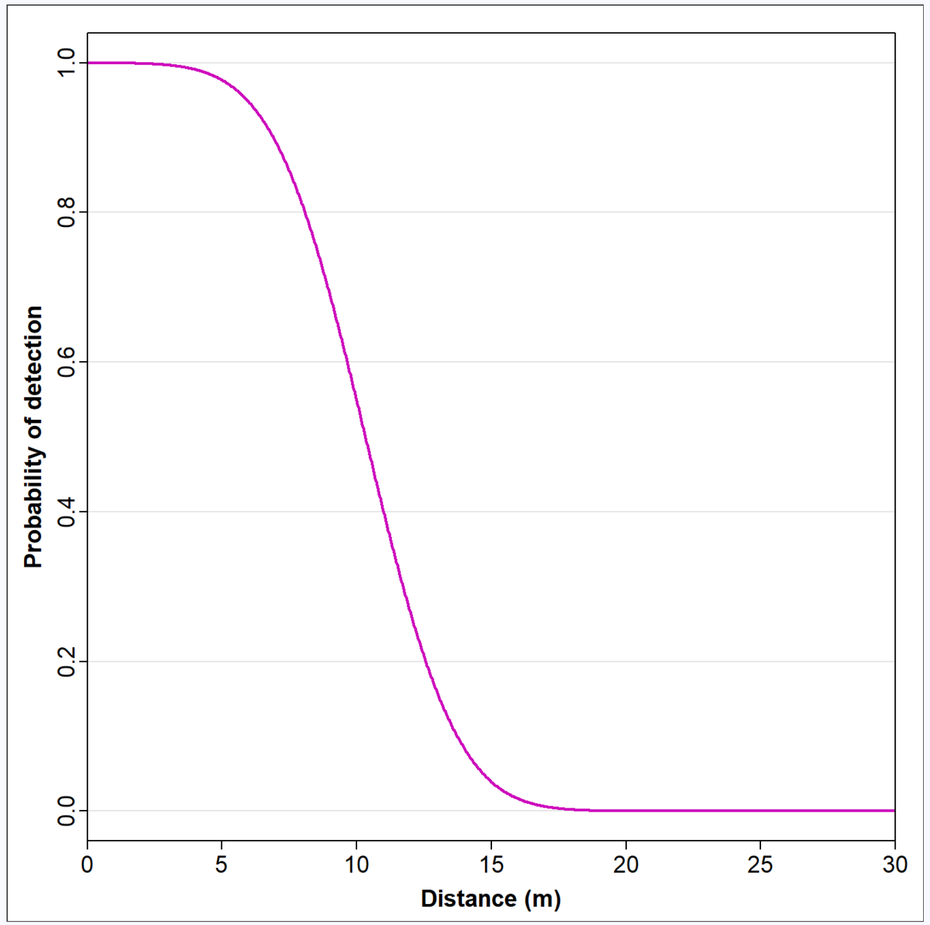

Figure: The **s**ignal **s**trength detection function used in the simulation study.

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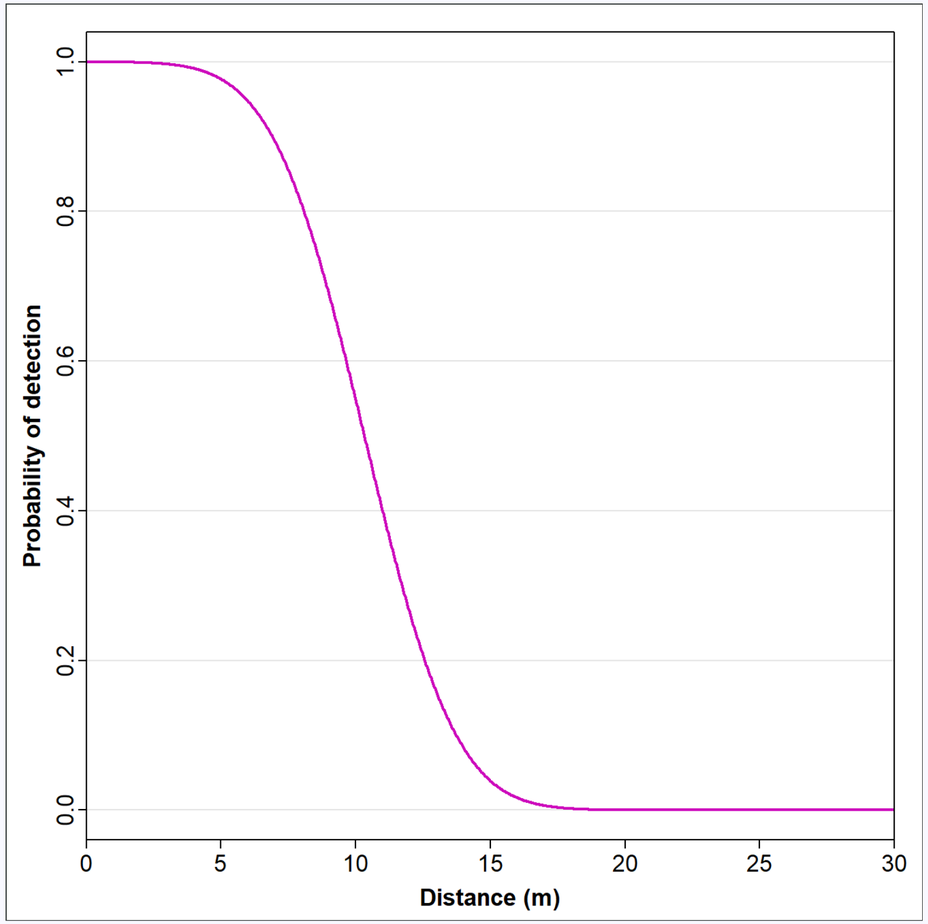
SS HN HR HHN



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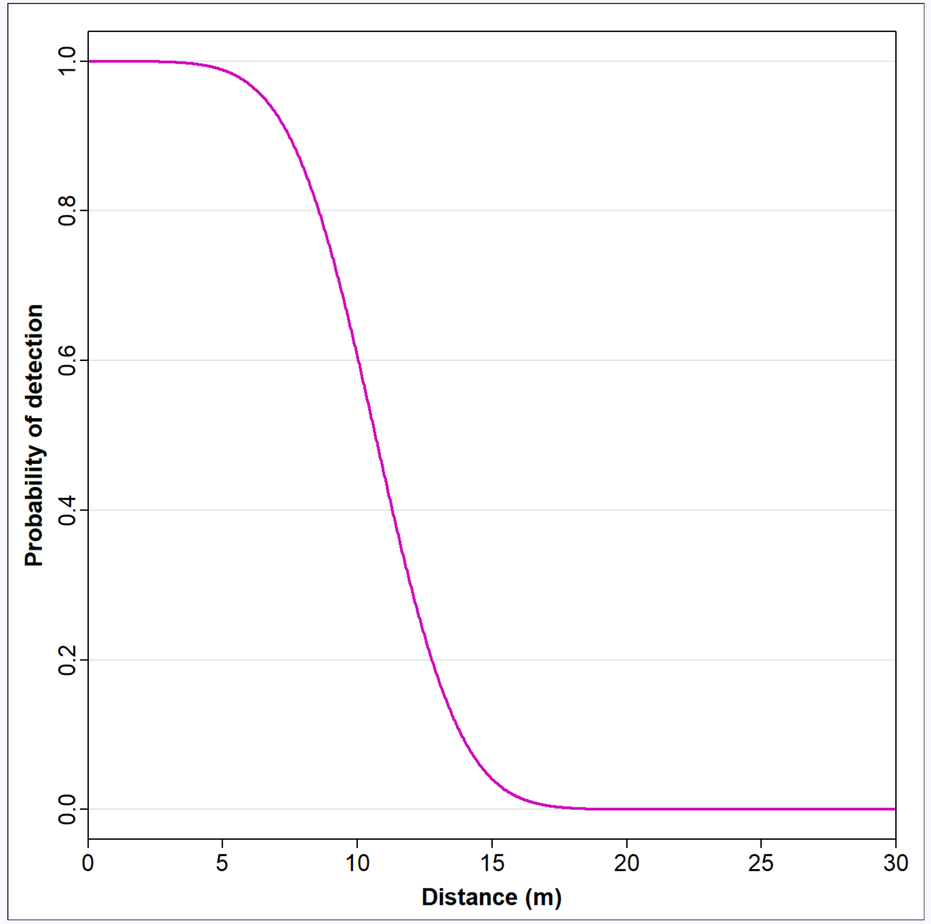

Figure: A fitted **s**ignal **s**trength detection function for one simulated dataset.

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Results: Density estimator performance

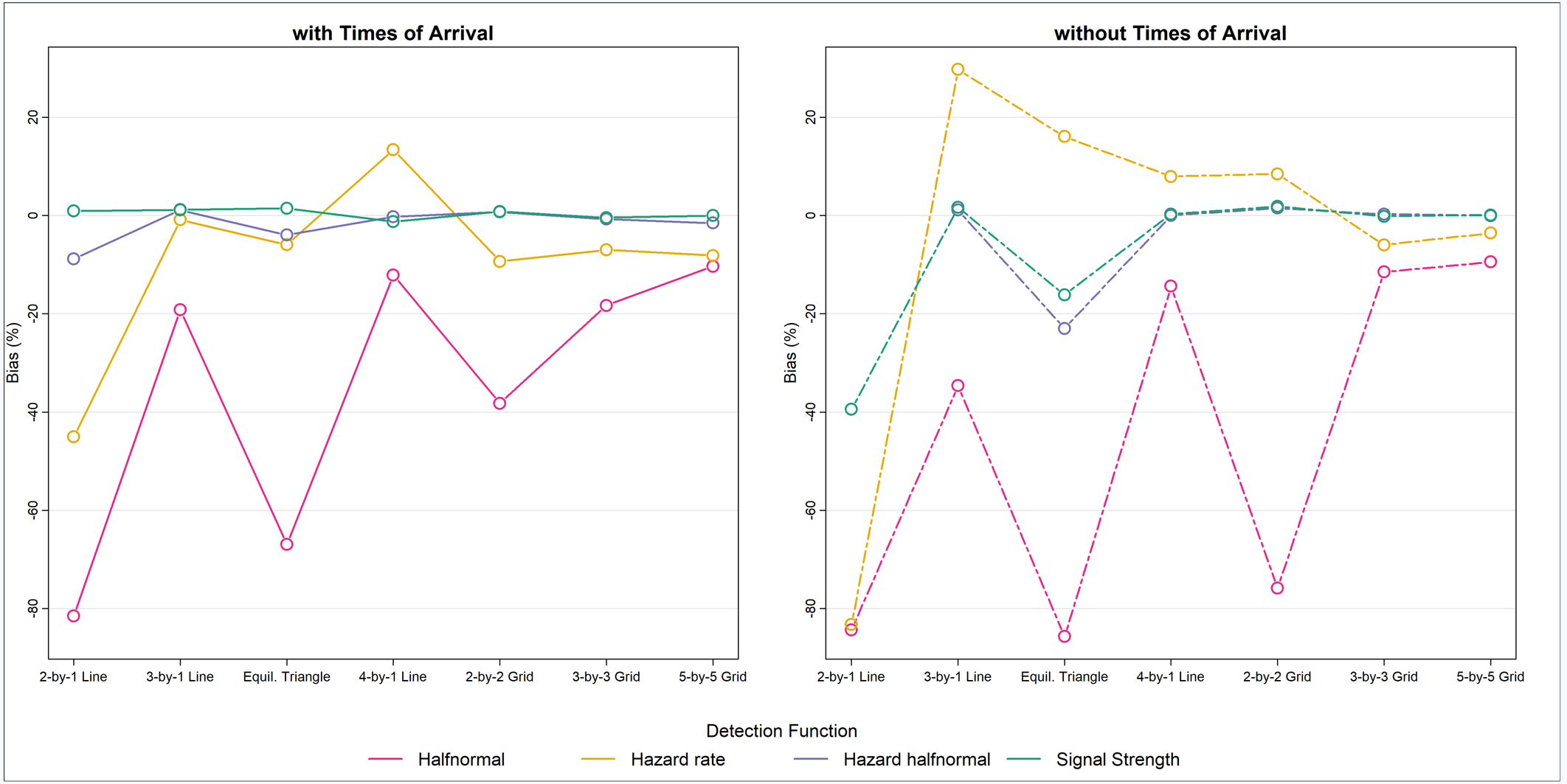

Figure: The relative bias of the call density estimator (%) by detection function and if the fitted SCR model included the times of arrival data or not (solid or dotted-dashed line).

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Results: AIC Support

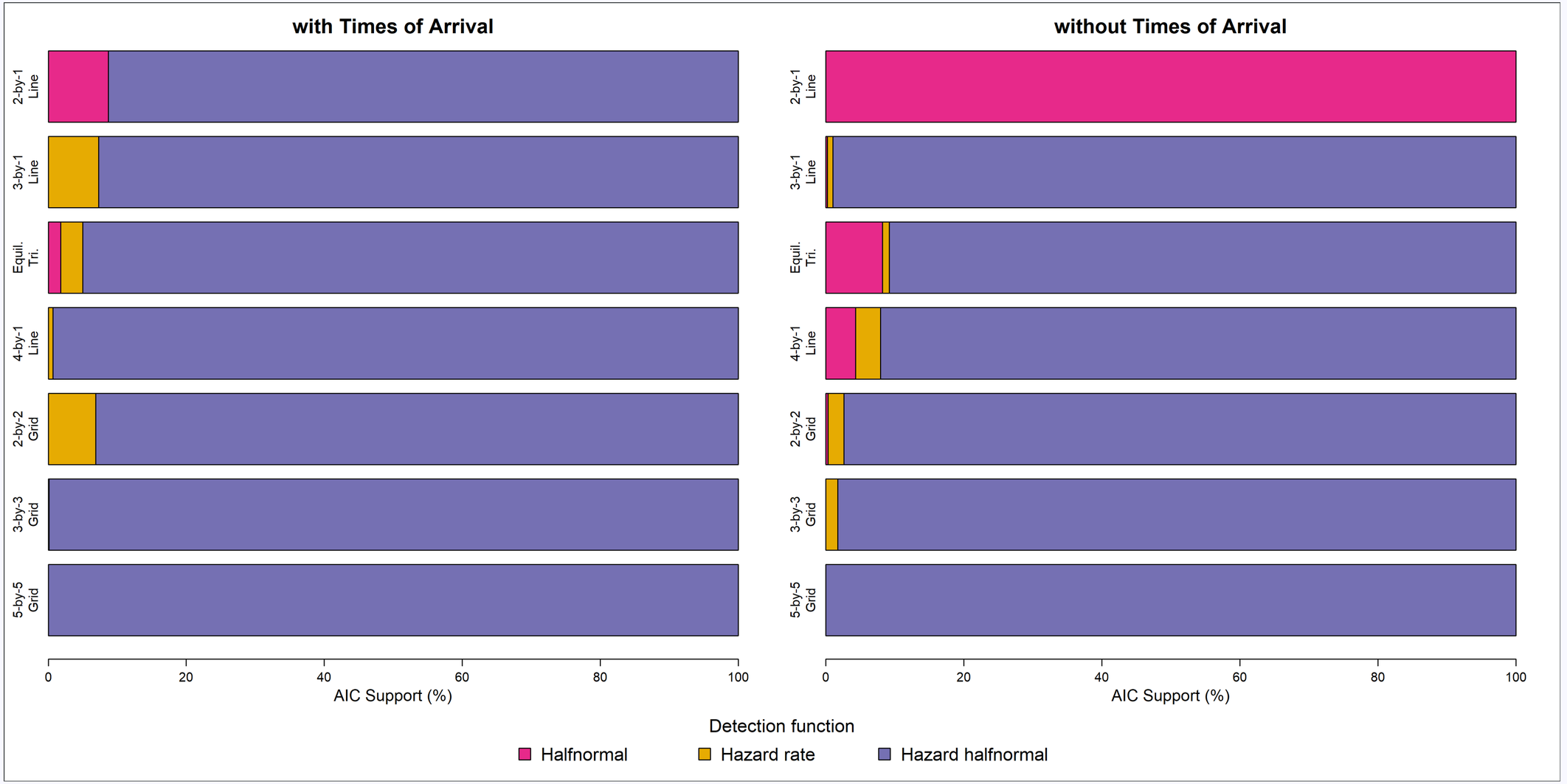

Figure: These stacked bar plots visualise the distribution (%) of which misspecified detection function had the highest AIC support for each simulated acoustic SCR dataset by survey design and the inclusion of the times of arrival data.

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Key takeaways

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- Model selection methods, like AIC, can identify an appropriate detection function from the data.

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Thanks!

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