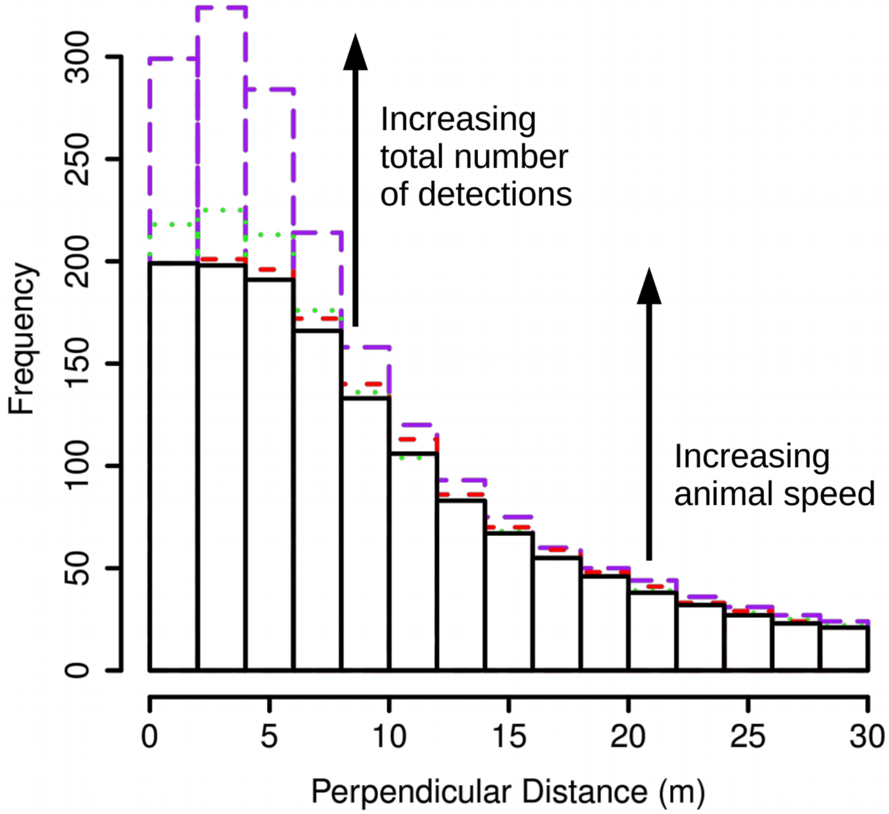
Distance sampling and animal movement



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CREEM
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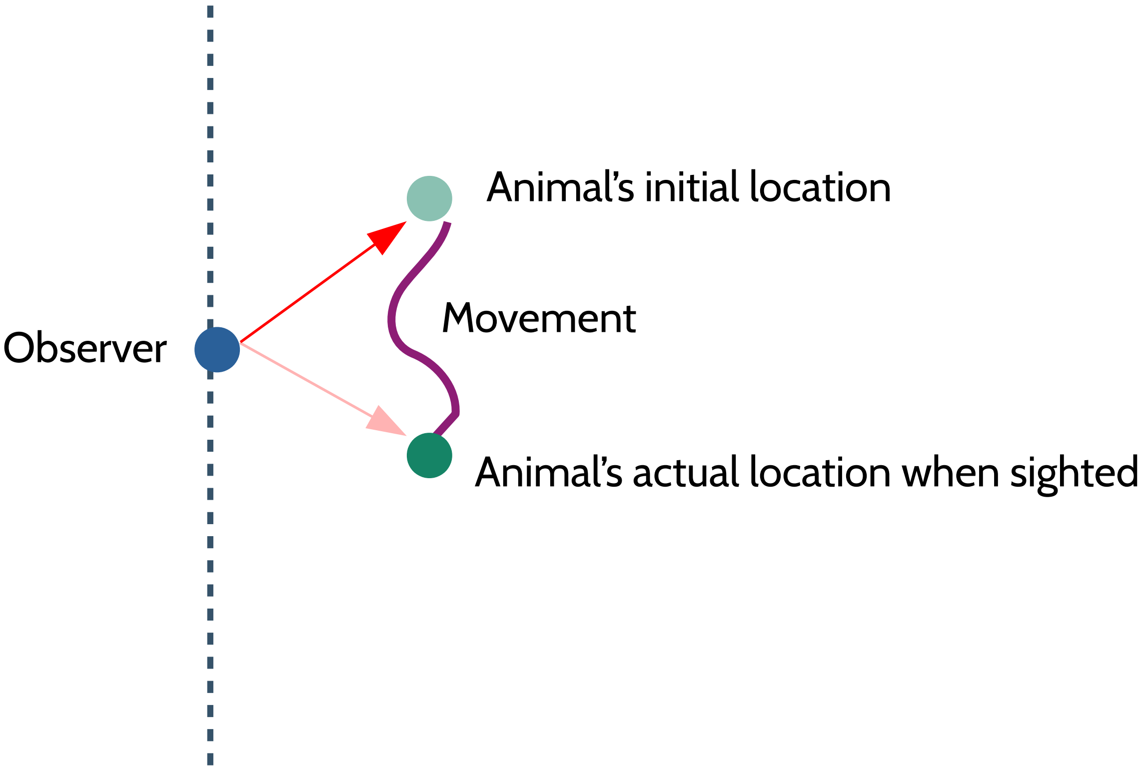
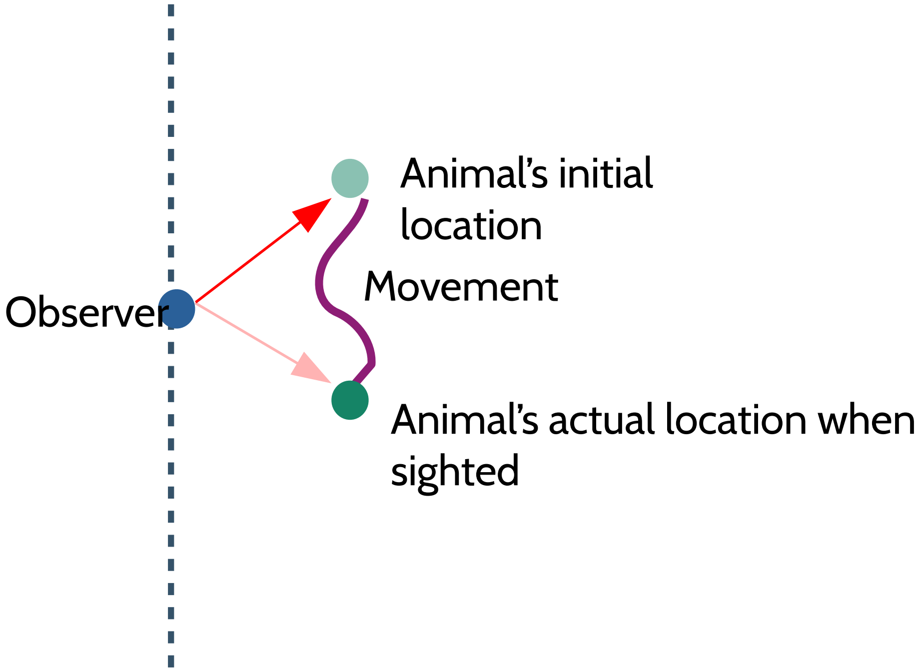
Assume: Animals are detected at their *initial* location.



Assume: Animals are detected at their *initial* location.

Similar Assumptions

- Animals do not move.
- Animals move slowly relative to the observer.
- Animals are detected before they respond.



Questions

Assume: Animals are detected at their initial location.

1) How badly does this assumption need to be violated until it is a problem worth worrying about?

2) How can the problems caused by these violations be mitigated?

Assume: Animals are detected at their *initial* location.

Violate: Move in <u>response</u> to observer.

Mitigate:

- ✓ Survey Protocol
- ✓ Left truncation
- ✓ 2D Models
- ✓ Double Observer Methods

Buckland, S.T., Rexstad, E.A., Marques, T.A. and Oedekoven, C.S., 2015. Distance sampling: methods and applications. New York, NY, USA: Springer.

Conn, P.B. and Alisauskas, R.T., 2018. Simultaneous modelling of movement, measurement error, and observer dependence in mark-recapture distance sampling: An application to Arctic bird surveys. The Annals of Applied Statistics, 12(1), pp.96-122.

Assume: Animals are detected at their *initial* location.

Violate: Move independently of the observer.

Mitigate: ?

Questions

Assume: Animals are detected at their initial location.

Violate: Move <u>independently</u> of the observer.

1) How badly does this assumption need to be violated until it is a problem worth worrying about?

2) How can the problems caused by these violations be mitigated?

Simulation

- Study population of 100 animals in 100 square kilometres.
- Animals move in Brownian motion at a particular movement rate.
- Do a point transect and line transect distance sampling. Line transect has width of 30 metres, point transect had radius of 100 metres.
- A two-dimensional hazard rate detection model was assumed, so hazard of detection was given by:

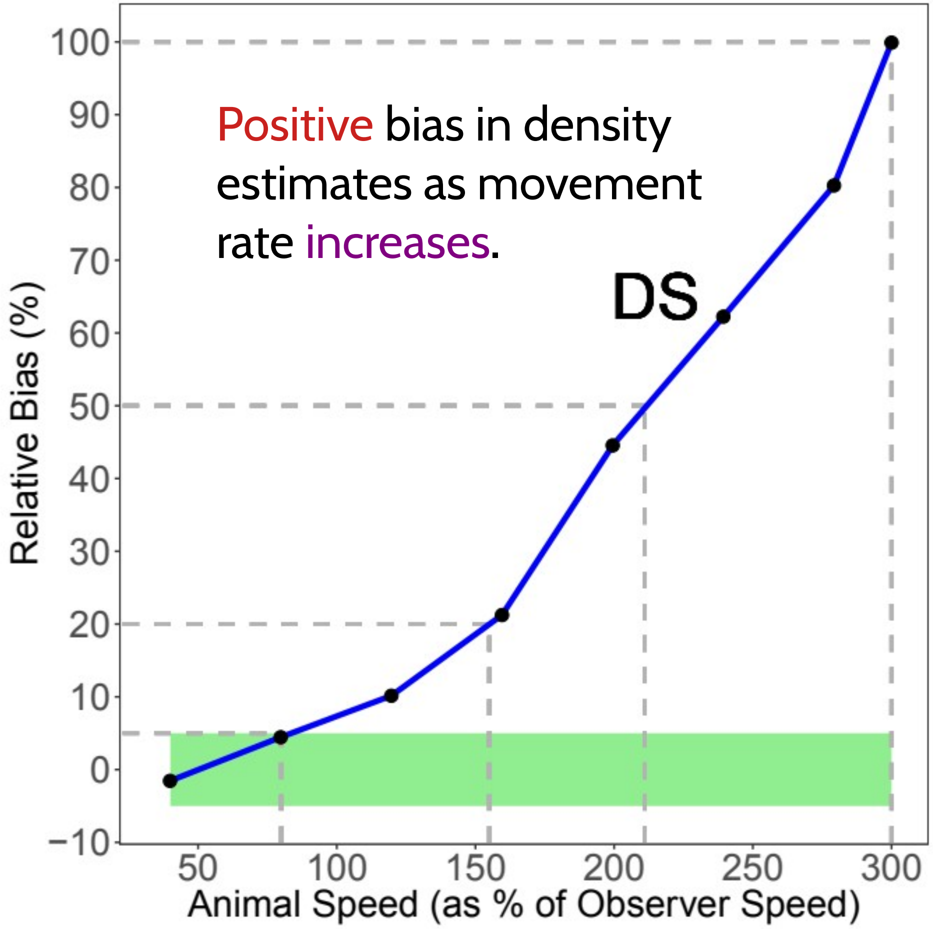
$$h(r) = \left(\frac{r}{s}\right)^{-d}$$

radius to animal

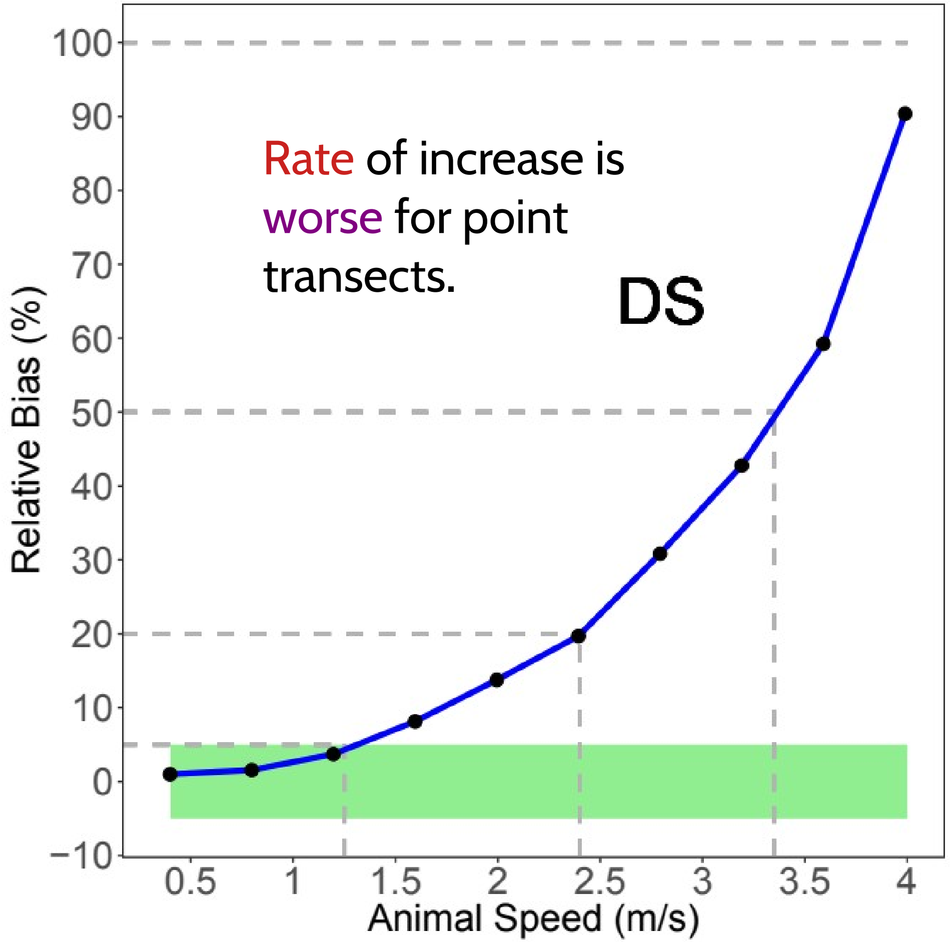
detection scale parameter

detection shape parameter

Simulation

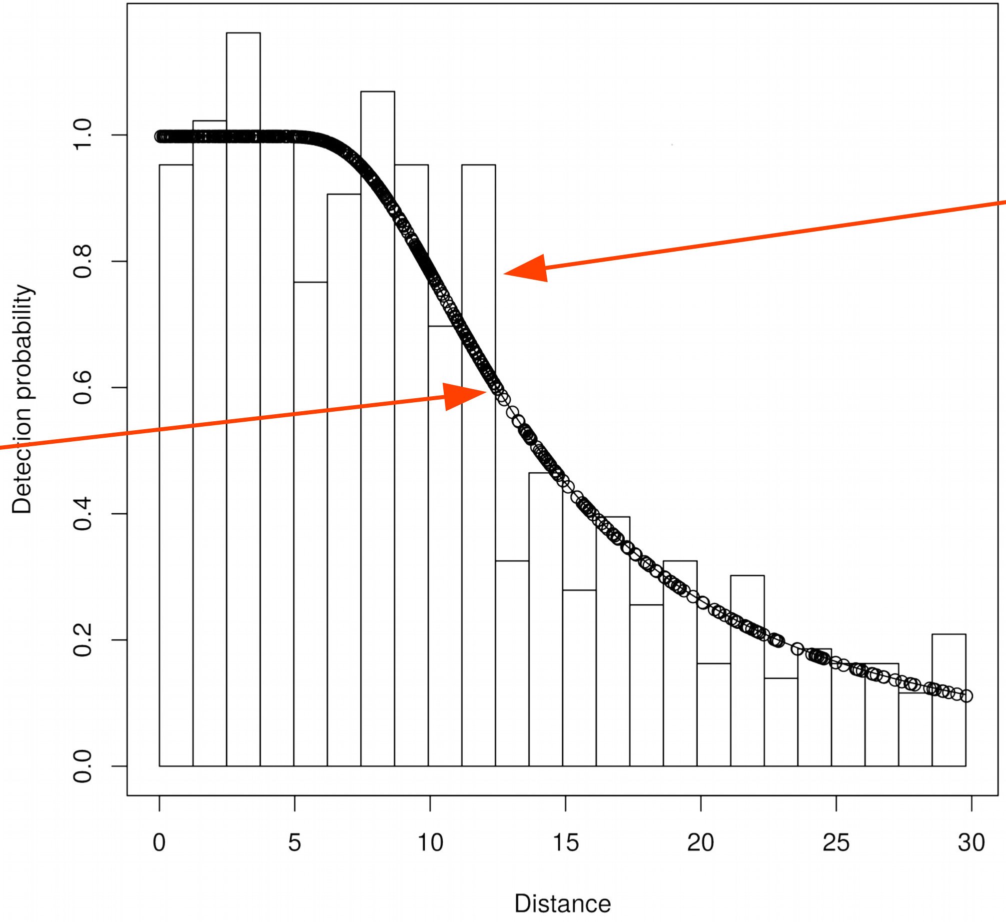


Line transects



Point transects

Area under estimated detection function is detection probability.



This distribution of observed distances needs to decline with detection function.

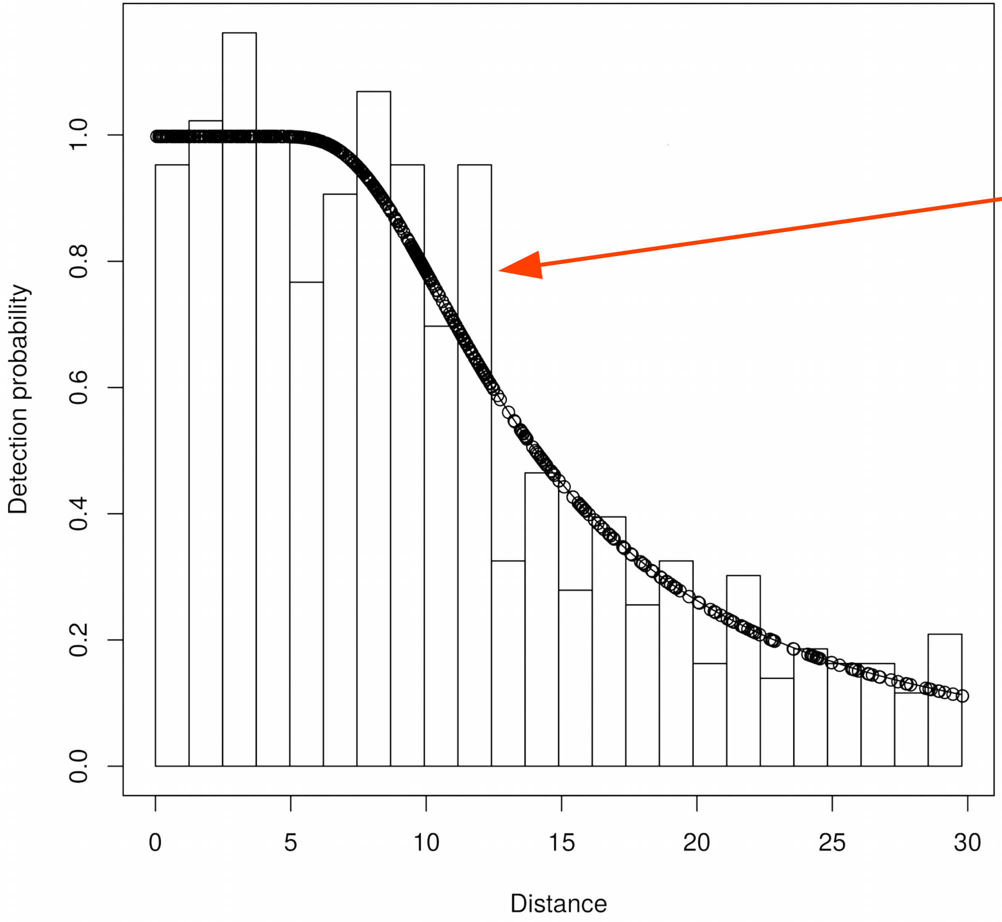
We know what causes bias when animals move in response to the observer.

$$\hat{N} = \frac{n}{\hat{p}}$$

Number seen

Detection probability

Abundance



Animals move toward observer means histogram declines too fast.

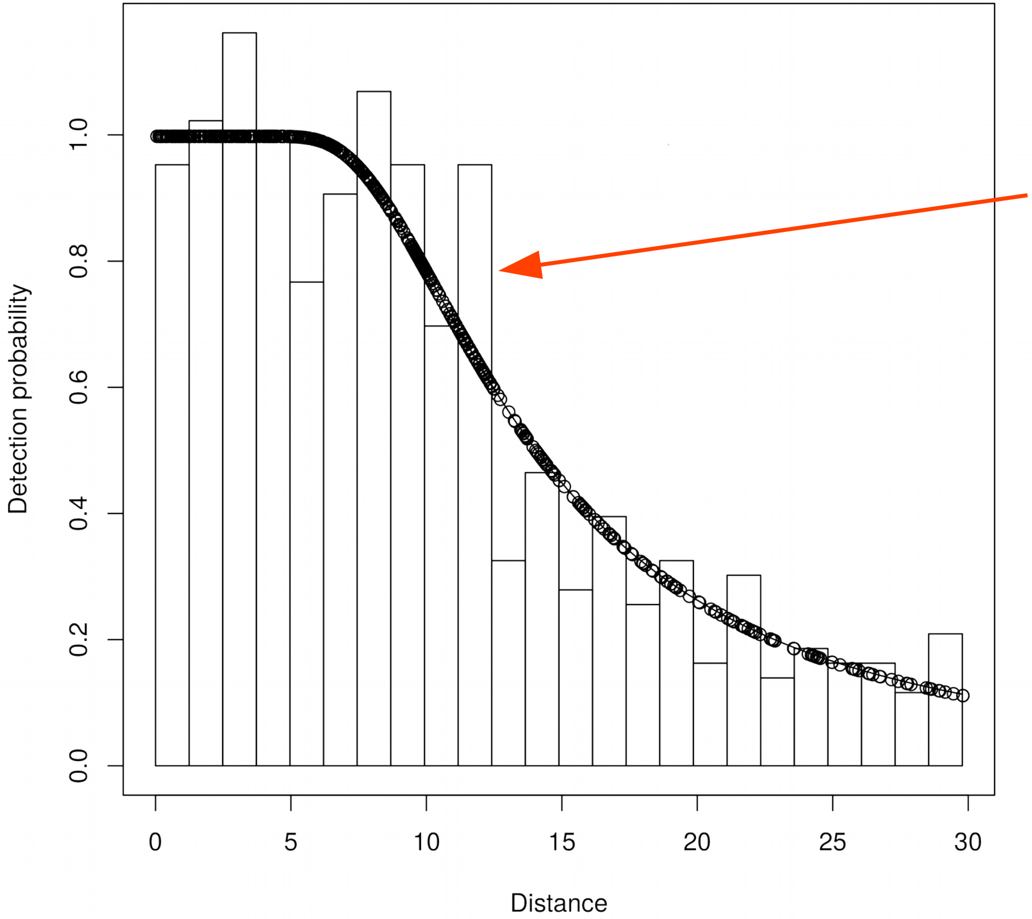
So we underestimate detection probability.

We know what causes bias when animals move in response to the observer.

Overestimate abundance

$$\hat{N} = \frac{n}{\hat{p}}$$

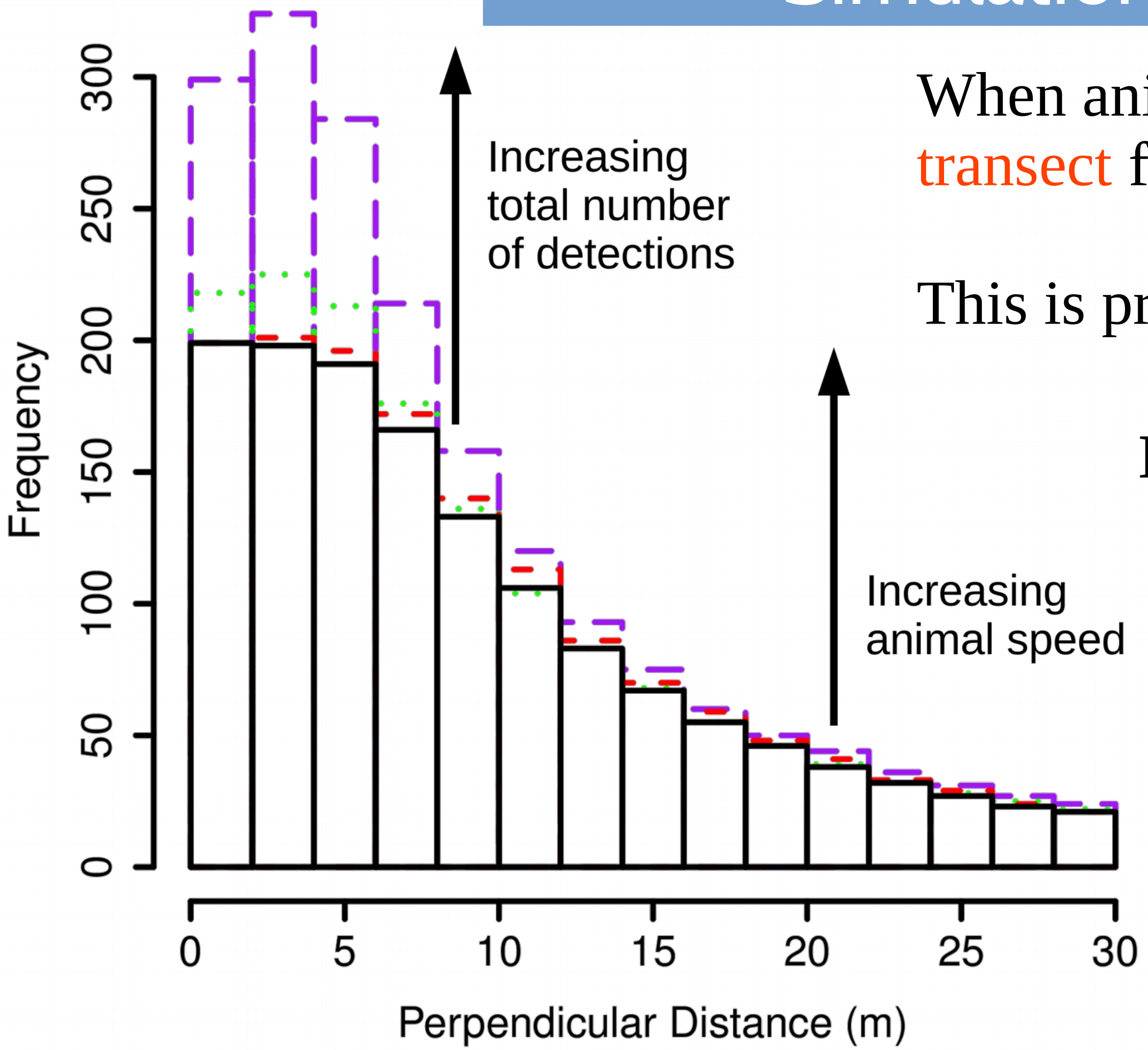
Underestimate detection probability



How does independent movement affect the distribution of observed locations?

We know what causes bias when animals move independently to the observer.

Simulation



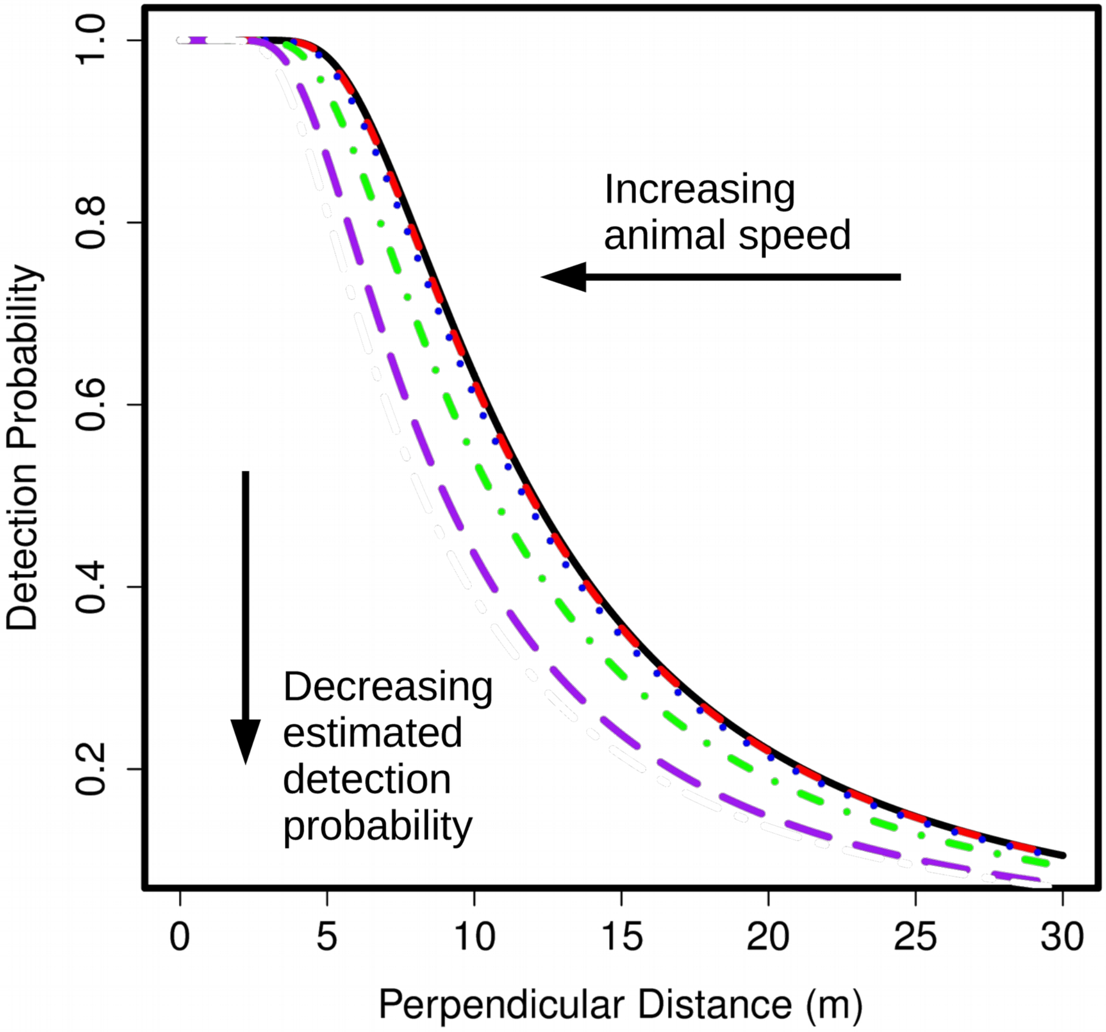
When animals move, more can enter the transect from the sides and be detected.

This is problem with strip transects too.

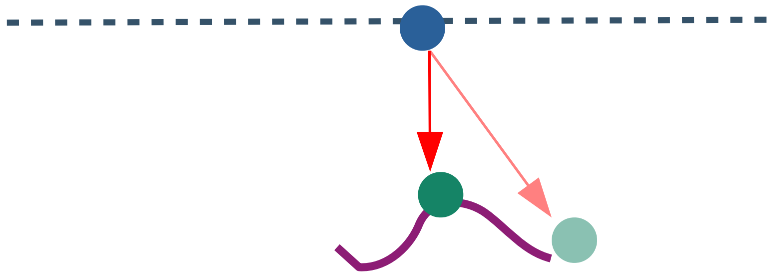
But what about the shape?

$$\uparrow \hat{N} = \frac{n}{\hat{p}} \uparrow$$

Simulation



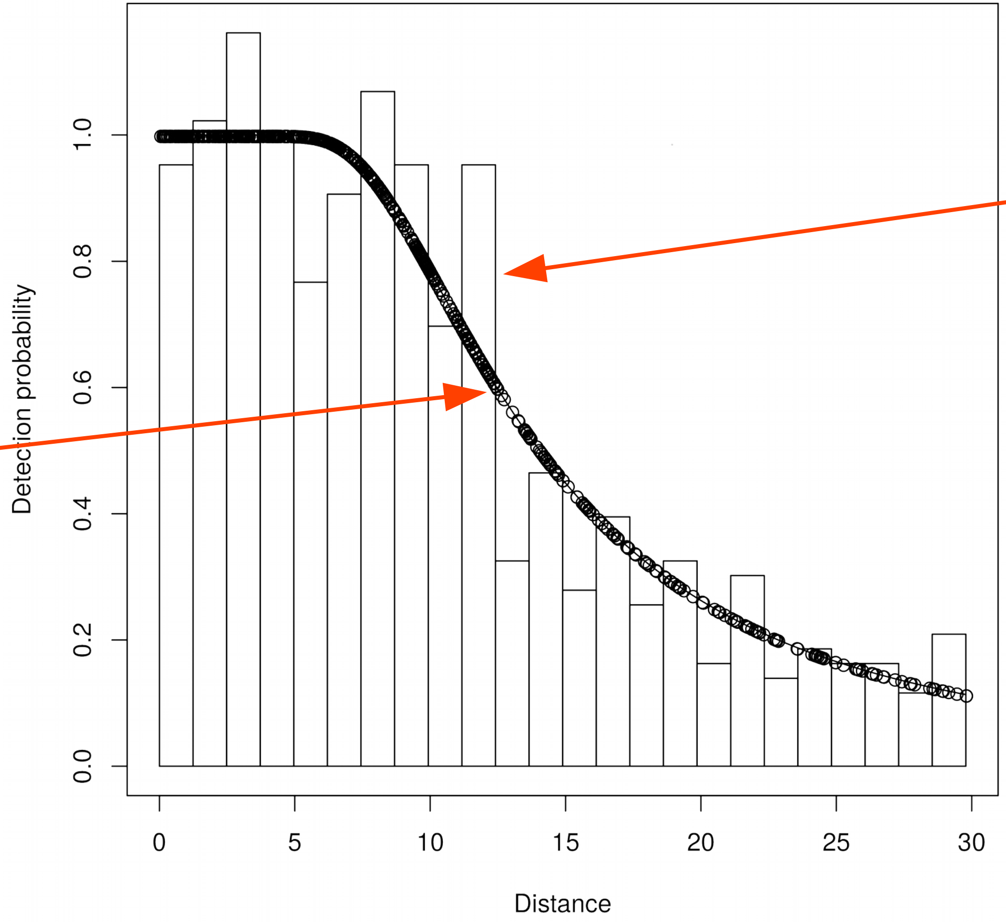
Animals are most likely to be seen at the location closest to the observer on their movement path.



$$\hat{N} = \frac{n}{\hat{p}}$$

Fundamentally...

Area under estimated detection function is too small.



This distribution of observed distances is produced by a mix of the detection process and the movement process.

Questions

Assume: Animals are detected at their initial location.

Violate: Move independently of the observer.

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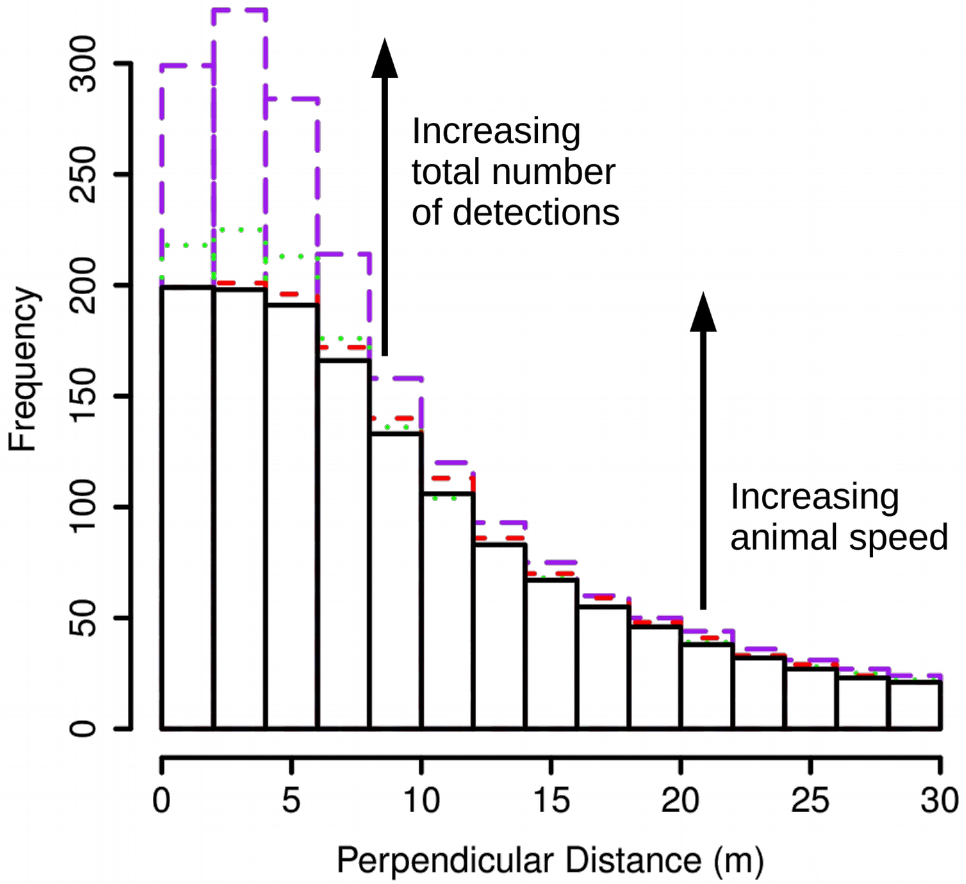
Assume: Animals are detected at their *initial* location.

Violate: Move <u>independently</u> of the observer.

Mitigate:

- ✓ Survey Protocol



Survey Protocol

1) Search out to further distances perpendicular to the line / radially from the point.

2) Ignore animals that overtake the observer. This is a large source of bias when animals move faster than the observer.

3) Use a snapshot protocol: record only when abeam in line transects or use a snapshot moment in point transects.

Glennie, R., Buckland, S.T. and Thomas, L., 2015. The effect of animal movement on line transect estimates of abundance. PloS one, 10(3), p.e0121333.

Assume: Animals are detected at their *initial* location.

Violate: Move <u>independently</u> of the observer.

Mitigate:

- ✓ Survey Protocol
- ✓ Truncate?

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Violate: Move <u>independently</u> of the observer.

Mitigate:

- ✓ Survey Protocol
- ✓ ~~Truncate?~~
- ✓ Model movement?

MDS Model

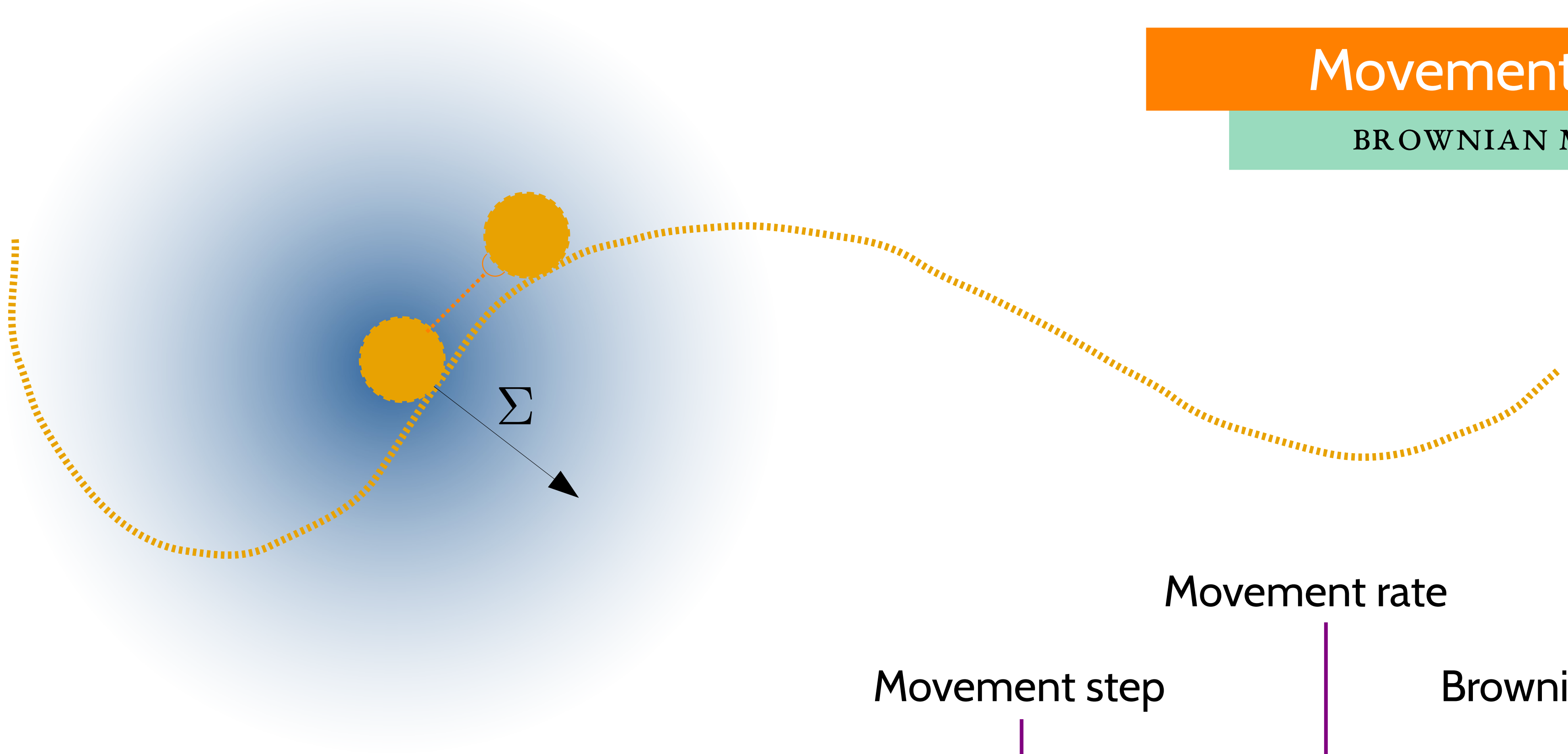
A distance sampling with movement (MDS) model requires two components:

- A detection model informed by the locations and times recorded during the distance sampling survey.

- A movement model informed by auxiliary data collected on the study species movement, e.g., recording repeated locations of individuals during the survey or by tagging animals.

Movement Model

BROWNIAN MOTION



Movement rate

Movement step

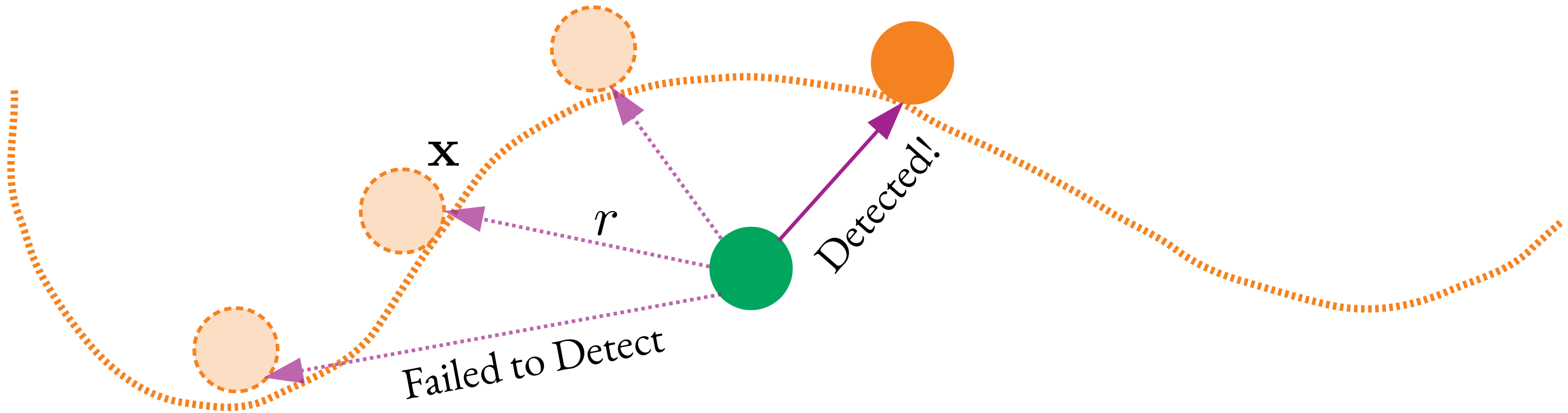
Brownian motion

$$d\vec{\mathbf{x}}_t = \Sigma_t(\vec{\mathbf{x}}_t)\ \mathrm{d}\mathbf{B}_t$$

Detection Model

A Hazard Survival Model

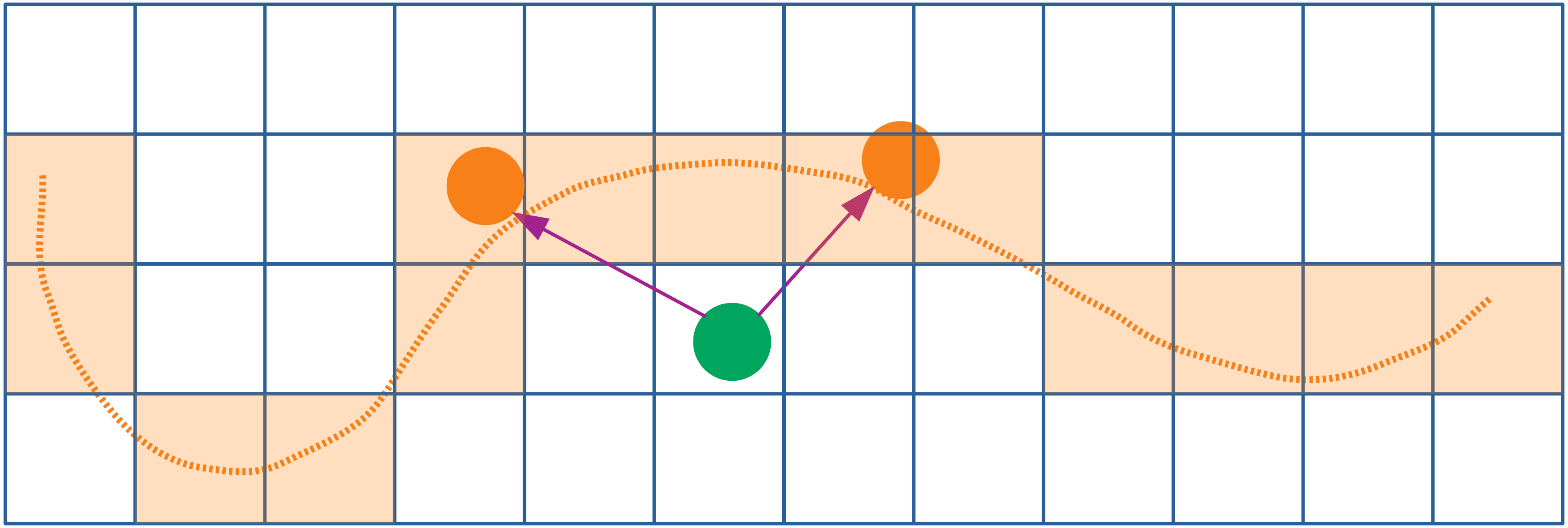
Problem is that path is unobserved except for one location.



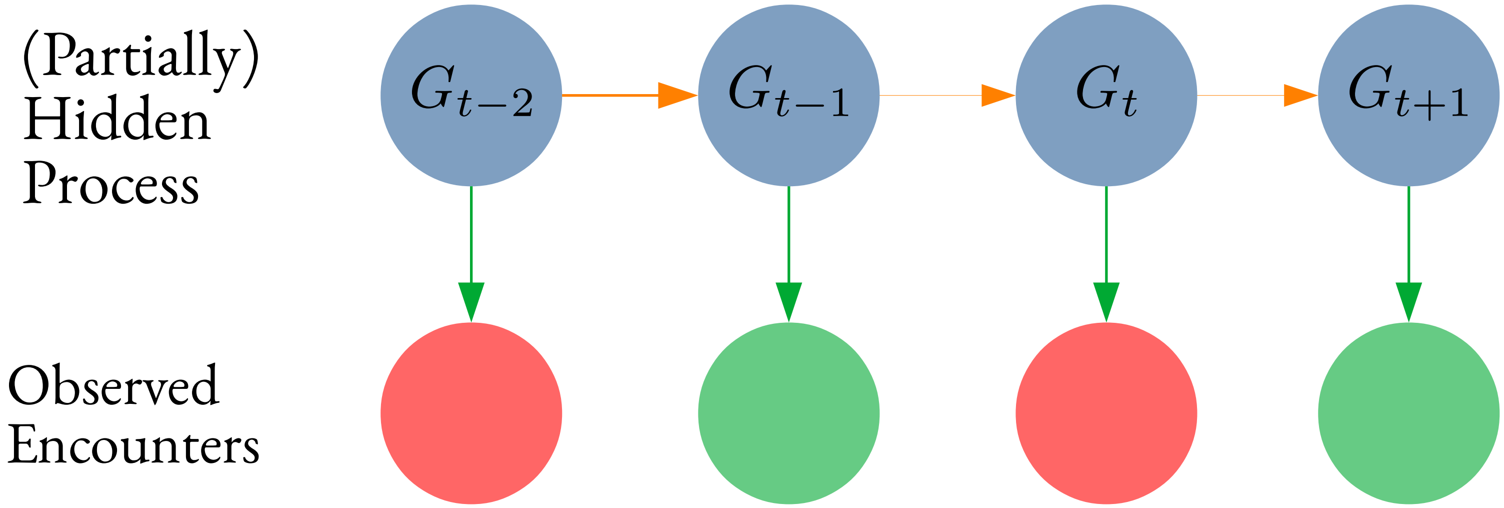
$$h_t(\mathbf{x}) = \frac{\alpha}{r_t(\mathbf{x})^2} \longrightarrow [t \mid \vec{\mathbf{x}}] = h_t(\vec{\mathbf{x}}_t)\exp\left(-\int_0^t h_s(\vec{\mathbf{x}}_s)\,\mathrm{d}s\right)$$

Detection function depends on the entire path travelled by the animal during surveying of that transect.

We need to integrate over the paths. We can do this by discretizing space and time.

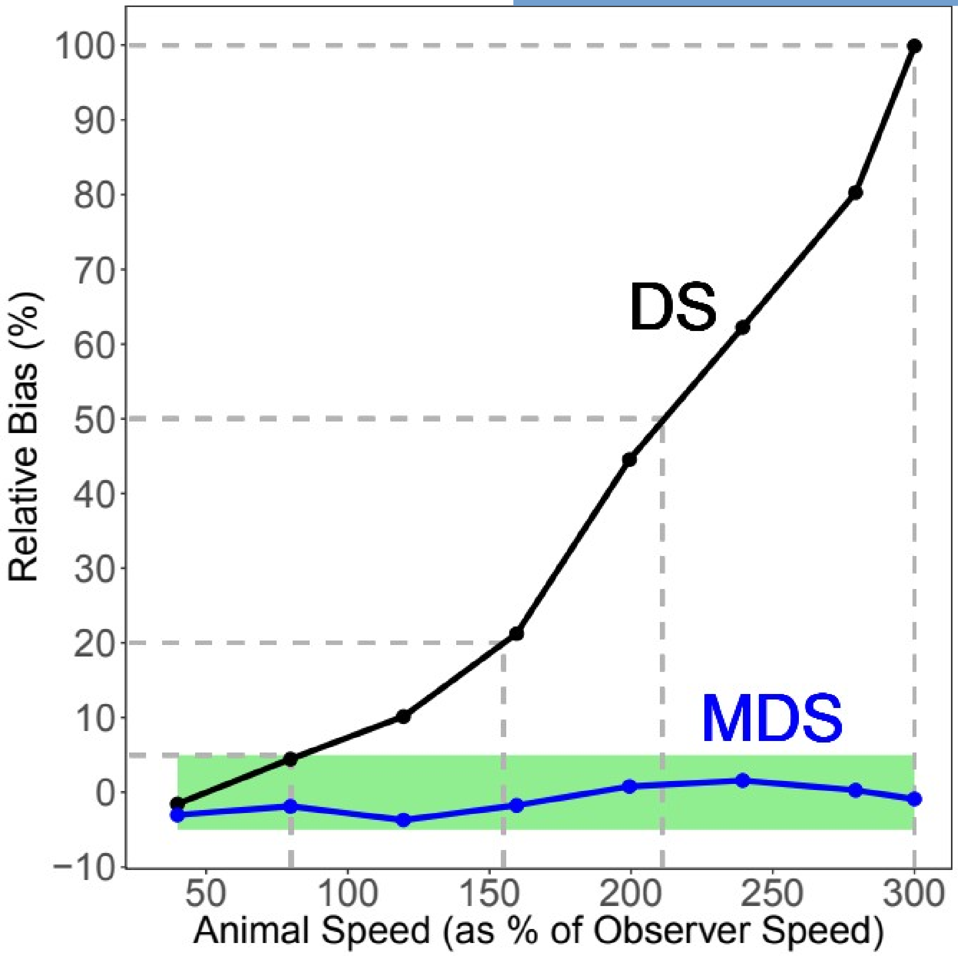


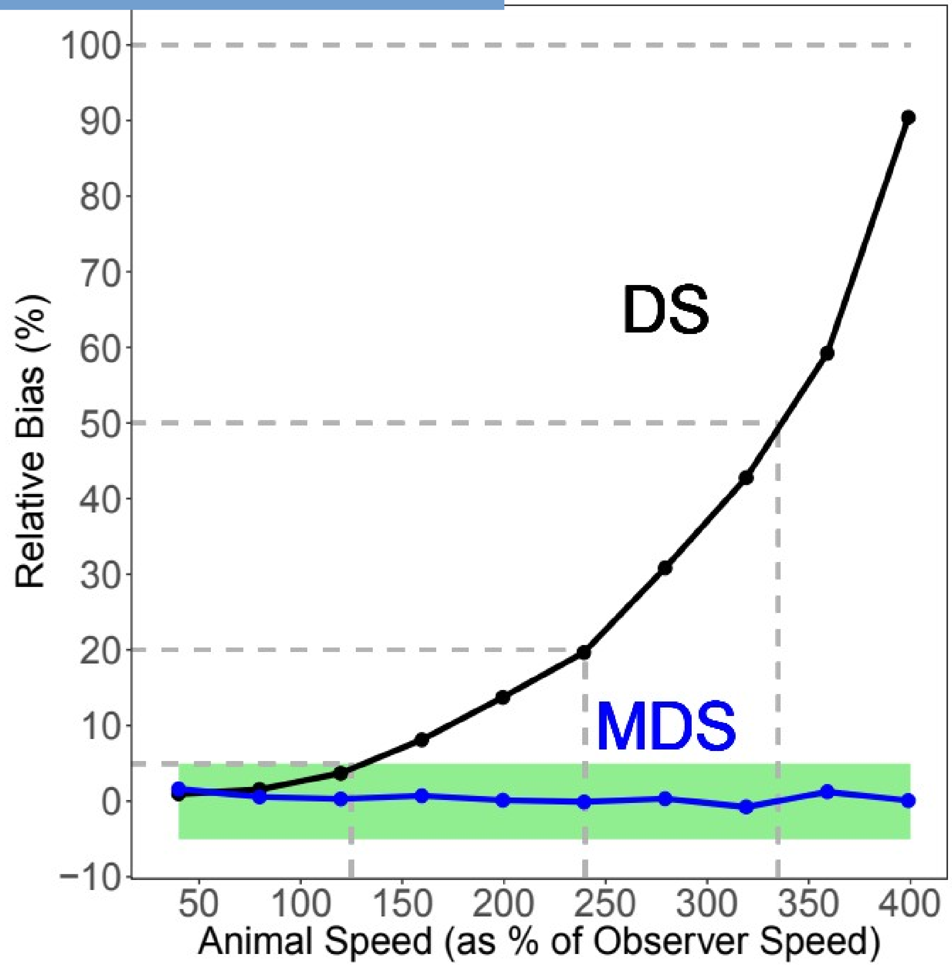
We need to integrate over the paths. We can do this by discretizing space and time. This is equivalent to a hidden Markov model.



There is an efficient algorithm to fit models of this form.

Simulation





LINE TRANSECTS

POINT TRANSECTS

Software

R package implementing this method available on GitHub.

README.md

moveds

Fits models that account for non-responsive, Brownian motion of individuals during distance sampling surveys.

Install

In R, the latest release can be installed using the `devtools` package with command

```
devtools::install_github("r-glennie/moveds@v0.1.0", build_vignettes = TRUE)
```

The package requires you have a C compiler installed on your system. Windows users may need to install R-tools for this reason. It is assumed Linux and Mac users have a compiler installed.

Extensions under development

1) Extending the method for slow-moving autonomous vehicles.

2) Allowing for acoustic / partial detection: estimate of what grid cells the animal is likely to be in, but do not know the exact one.

3) State-switching animal movement models: animals can switch between states with different movement and detection properties, e.g., diving-surface.

4) Responsive movement models: collect auxiliary data on how animals respond and incorporate this behaviour.

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