Distance sampling and animal movement

Increasing total number of detections

Increasing animal speed

Perpendicular Distance (m)

Frequency
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.
**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 response to observer.

Mitigate:

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


Assume: Animals are detected at their initial location.

Violate: Move independently of the observer.

Mitigate: ?
Assume: Animals are detected at their initial location.

Violate: Move independently 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?
• 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:

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

- \( r \): radius to animal
- \( s \): detection scale parameter
- \( d \): detection shape parameter
Line transects

Simulation

Positive bias in density estimates as movement rate increases.

Rate of increase is worse for point transects.

Point transects
We know what causes bias when animals move in response to the observer. This distribution of observed distances needs to decline with detection function. Area under estimated detection function is detection probability.
\[ \hat{N} = \frac{n}{\hat{p}} \]

- \( \hat{N} \): Abundance
- \( n \): Number seen
- \( \hat{p} \): Detection probability
We know what causes bias when animals move in response to the observer. Animals move toward observer means histogram declines too fast. So we underestimate detection probability.
Overestimate abundance

\[ \hat{N} = \frac{n}{\hat{p}} \]

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

How does independent movement affect the distribution of observed locations?
Simulation

When animals move, more can enter the transect from the sides and be detected. This is a problem with strip transects too.

But what about the shape?

\[
\hat{N} = \frac{n}{\hat{p}}
\]
Animals are most likely to be seen at the location closest to the observer on their movement path.
This distribution of observed distances is produced by a mix of the detection process and the movement process.

Fundamentally...

Area under estimated detection function is too small.
Assume: Animals are detected at their initial location.

Violate: Move independently 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?
Assume: Animals are detected at their initial location.

Violate: Move independently 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.

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

Violate: Move *independently* of the observer.

Mitigate:

✓ Survey Protocol

✓ Truncate?
Assume: Animals are detected at their initial location.

Violate: Move independently of the observer.

Mitigate:

- Survey Protocol
- Truncate?
- Model movement?
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 step

Movement rate

Brownian motion

\[ d\mathbf{x}_t = \Sigma_t(\mathbf{x}_t) \ dB_t \]
Detection function depends on the entire path travelled by the animal during surveying of that transect.

\[ h_t(x) = \frac{\alpha}{r_t(x)^2} \]

\[ [t \mid \vec{x}] = h_t(\vec{x}_t) \exp \left( -\int_0^t h_s(\vec{x}_s) \, ds \right) \]
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.
R package implementing this method available on GitHub.

**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

```r
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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