# SEEC Toolbox seminars

## Animal movement modelling with `moveHMM`

Theoni Photopoulou
theoni.photopoulou@uct.ac.za

theoni_p

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# Brief overview

## Animal movement data

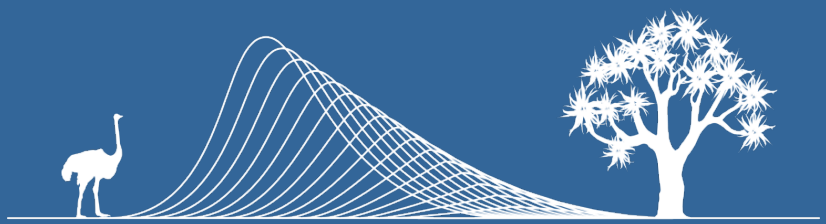
- What is it
- Why is it interesting
- What do we want to know

## Analysing movement data with HMMs

- What are they
- Why they are useful
- What you can and cannot do with HMMs

## Example with wild haggis data using `moveHMM`

## Useful resources





# Animal movement data

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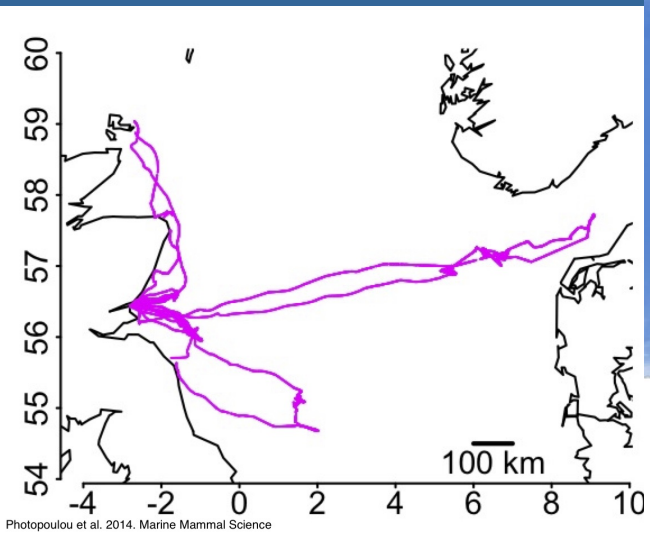
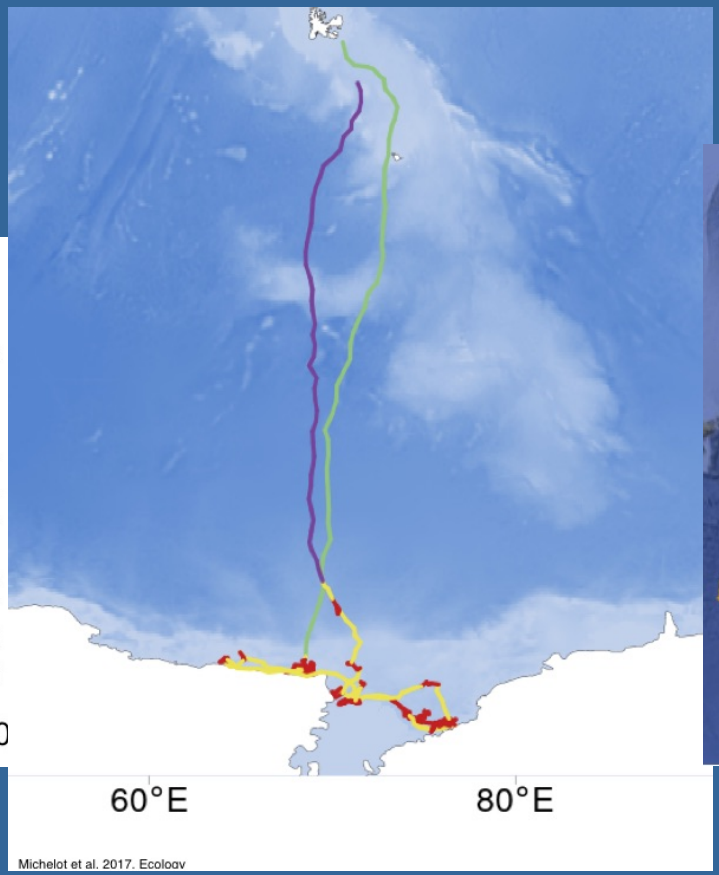
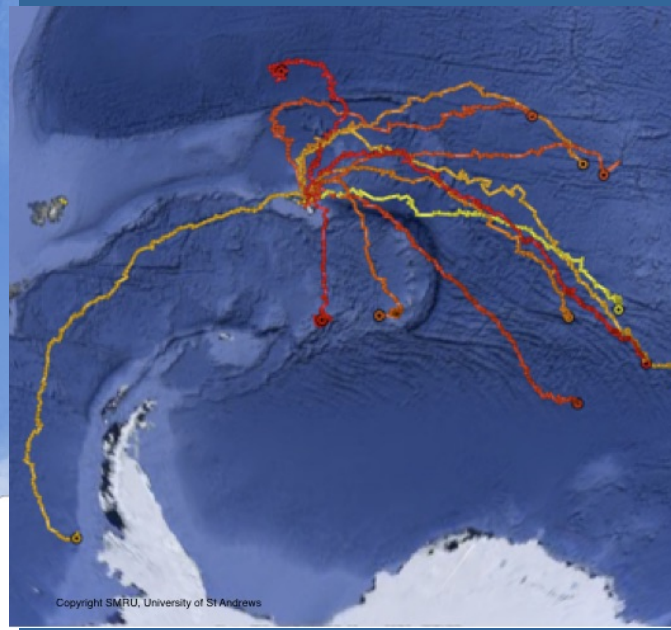


Photopoulou et al. 2014. Marine Mammal Science



Michelot et al. 2017. Ecology

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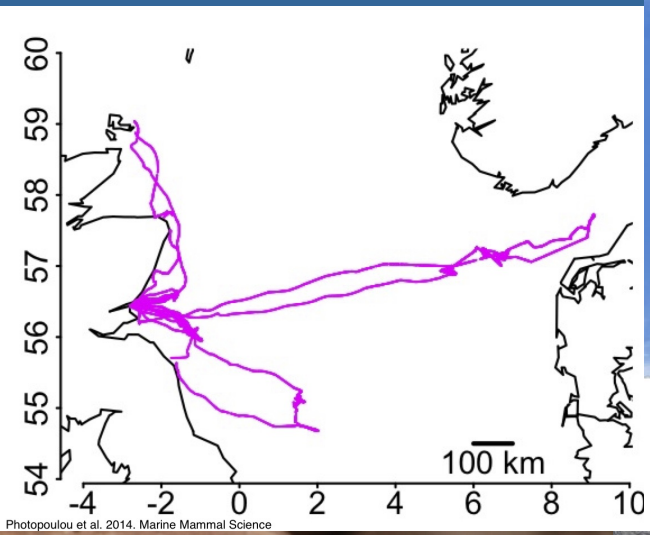

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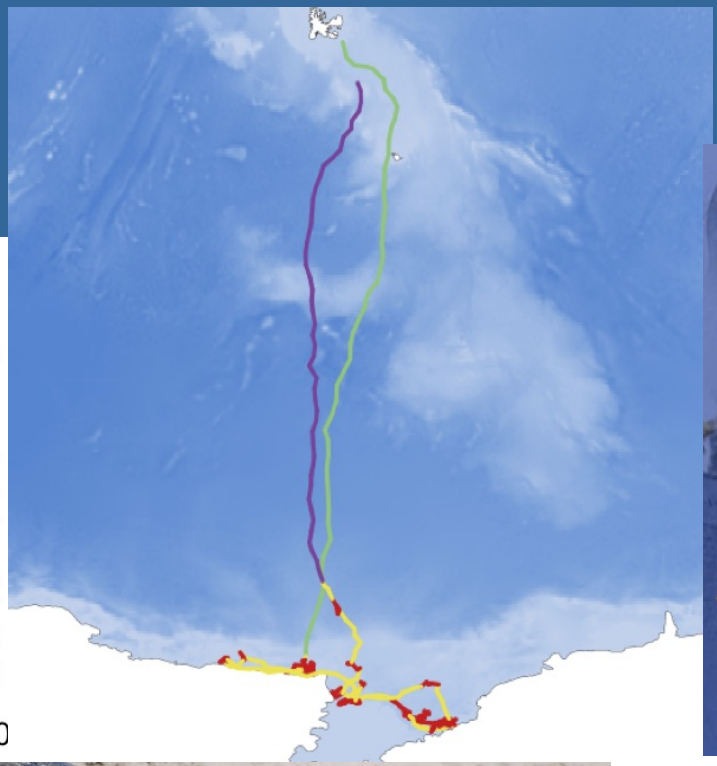
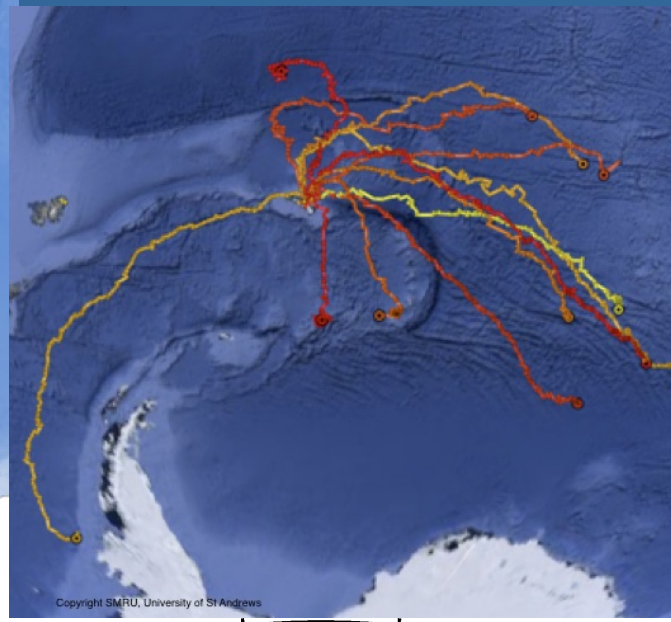
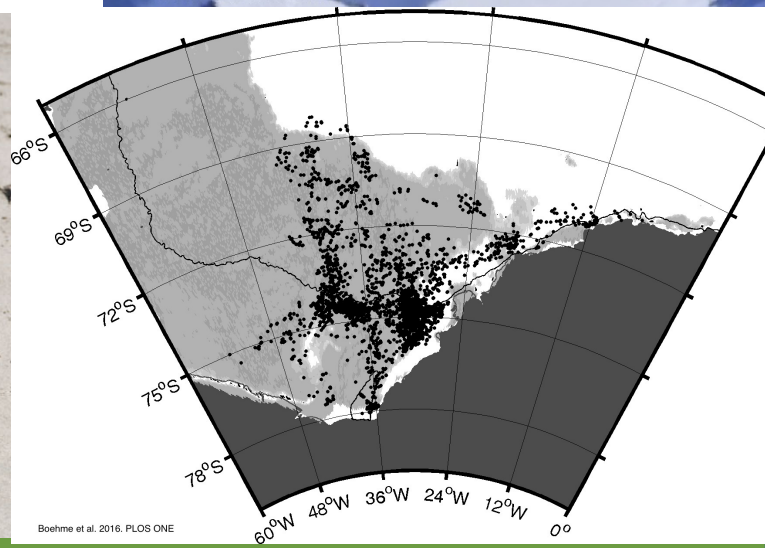






Boehme et al. 2016. PLOS ONE

# Animal movement data

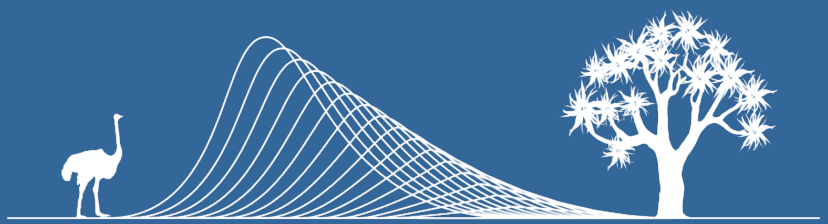
## Main features

$\Rightarrow$ Tags can collect very large volumes of data

$\Rightarrow$ Animal tracks have specific characteristics that set them apart

- Spatial and temporal structure

$\Rightarrow$ Analysis: step length and turning angle





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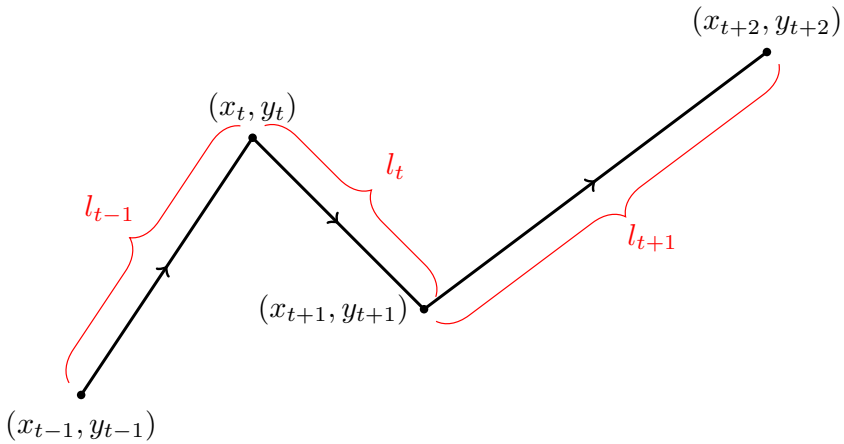


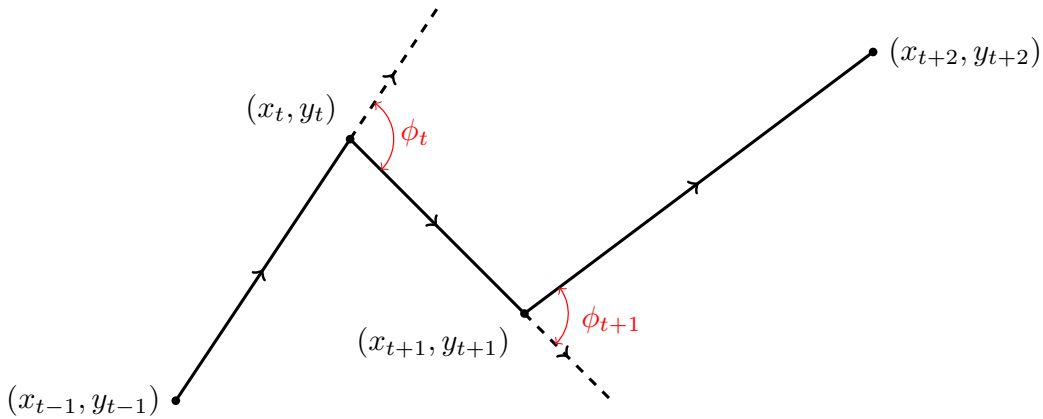

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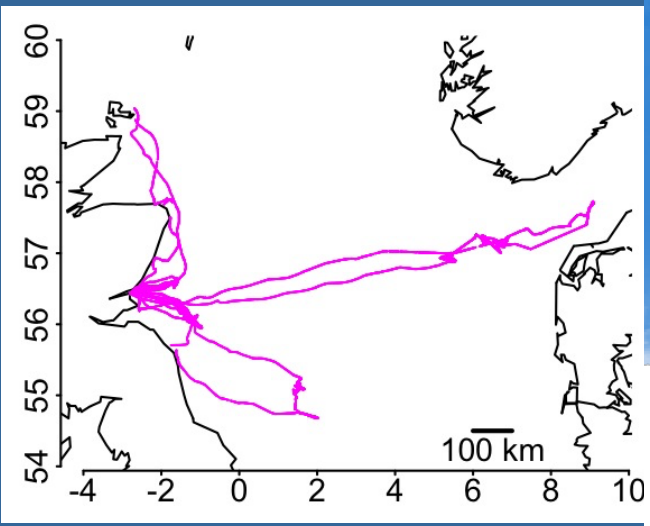


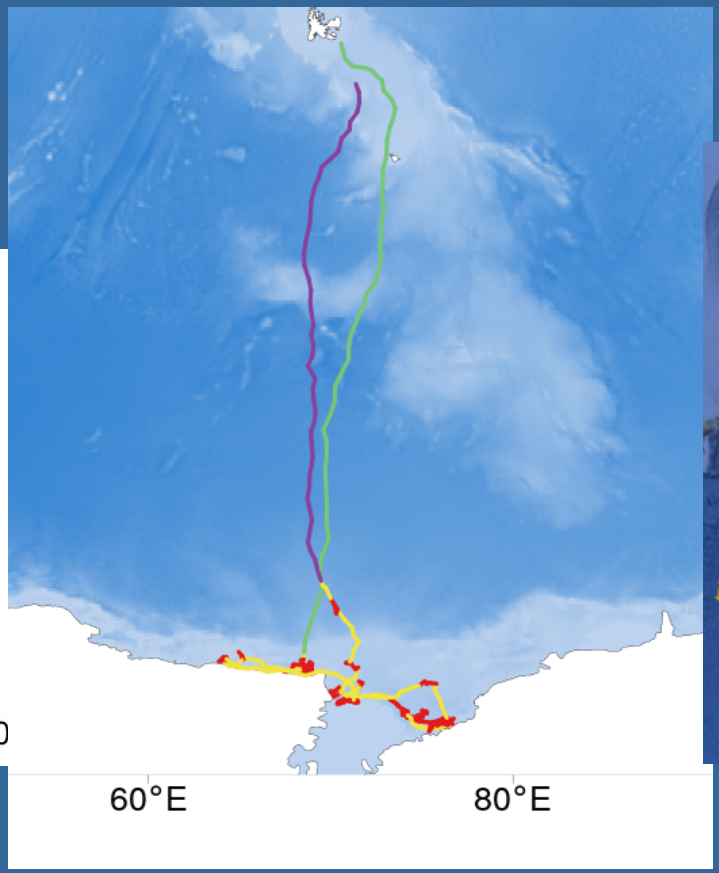


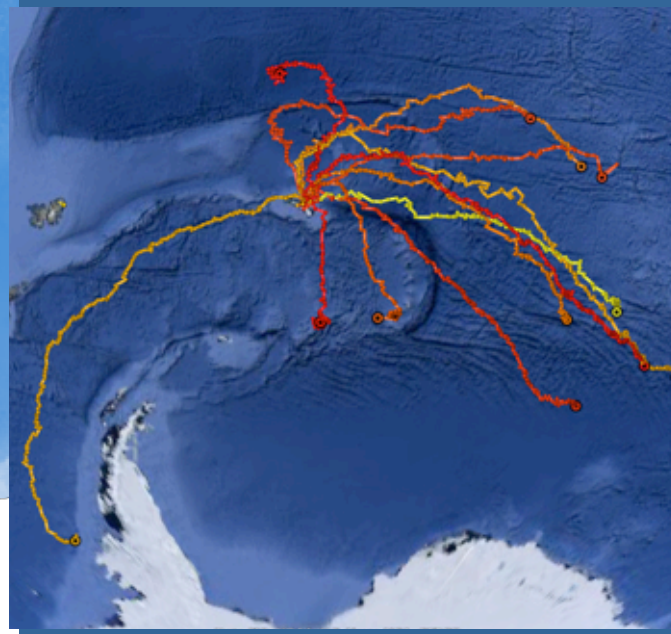

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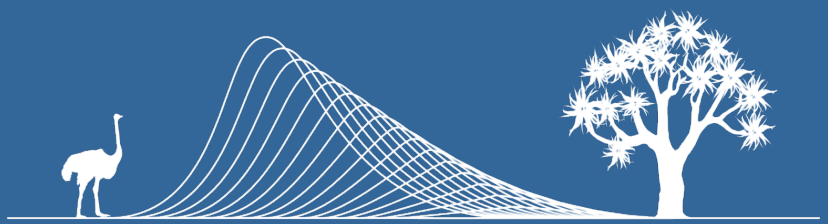
## Why it is interesting?

$\Rightarrow$ Locations don't just tell us where and when we observed an animal

$\Rightarrow$ We can convert locations into quantities that are measurable and that tell us something about animal behaviour





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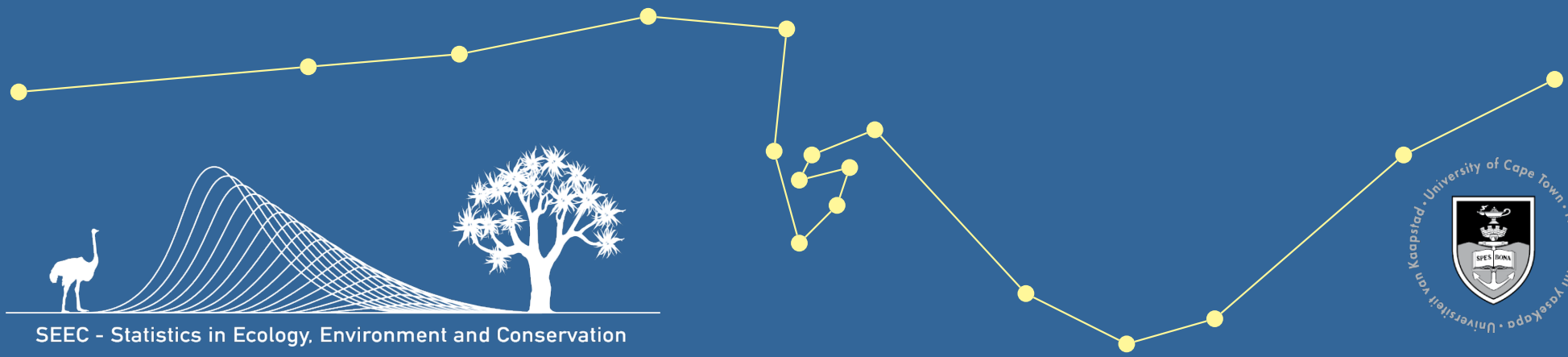
$\Rightarrow$ Step length tells us about speed

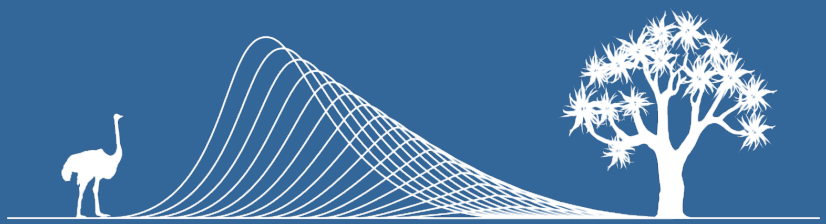
$\Rightarrow$ Turning angle tells us about straightness



# Animal movement data

## What do we want to know?

$\Rightarrow$ A lot of the time when collecting tracking data we want to know what the animal is "doing"





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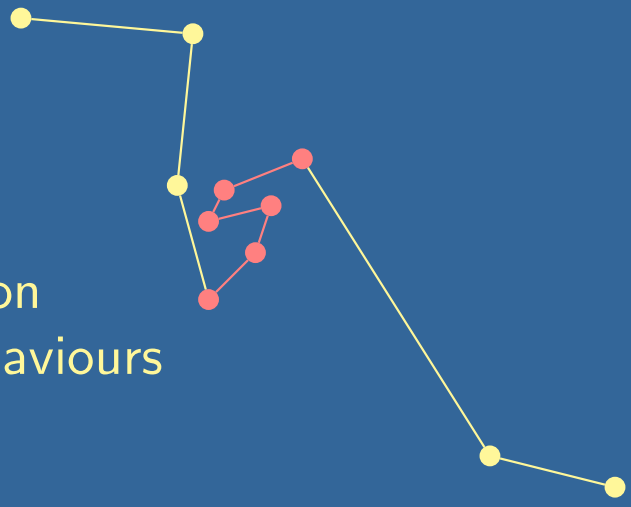

⇒ Describe different movement modes or "states" along a track

1. link state to the conditions at that location
2. loosely connect states to functions or behaviours

⇒ One way of doing this is with HMMs

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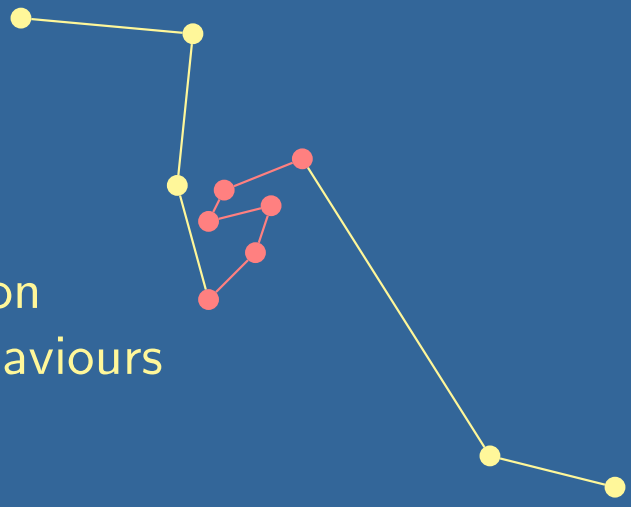

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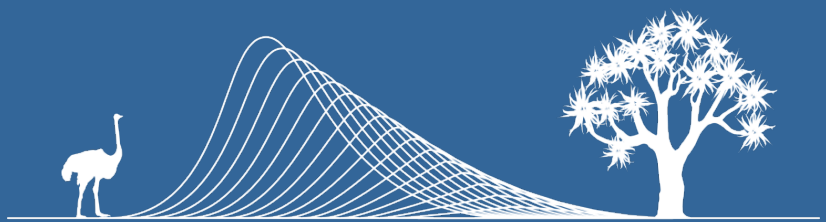
⇒ One way of doing this is with HMMs

DISCLAIMER! HMMS ARE DATA-DRIVEN
THERE IS NO GUARANTEE STATES WILL CORRESPOND TO BEHAVIOURS

# Analysing movement data with HMMs

## What are Hidden Markov Models?

$\Rightarrow$ HMMs are time series models made up of two processes or levels





# Analysing movement data with HMMs

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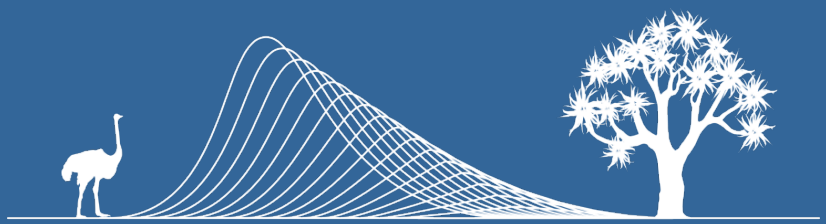



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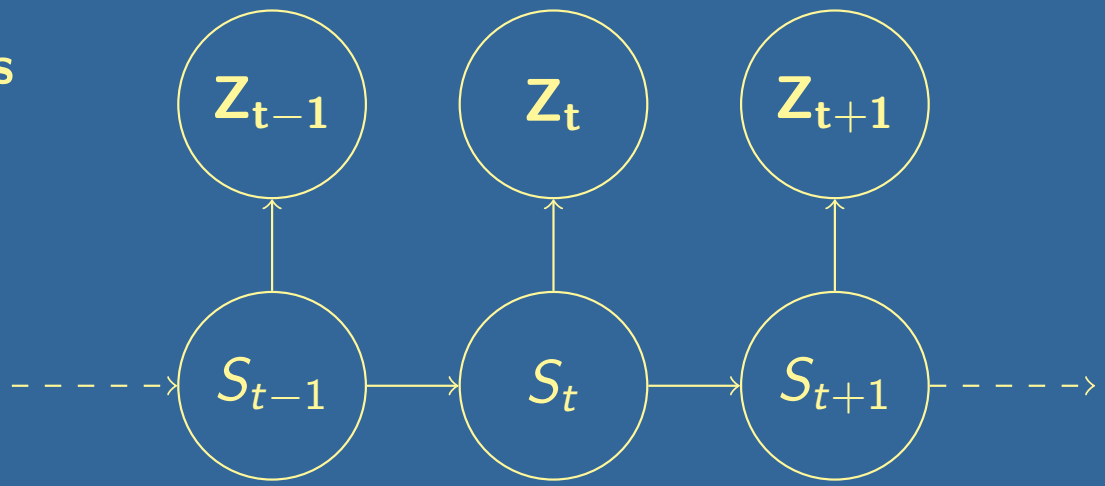
**state-dependent process**
(observed)

**state process**
(hidden)



# Analysing movement data with HMMs

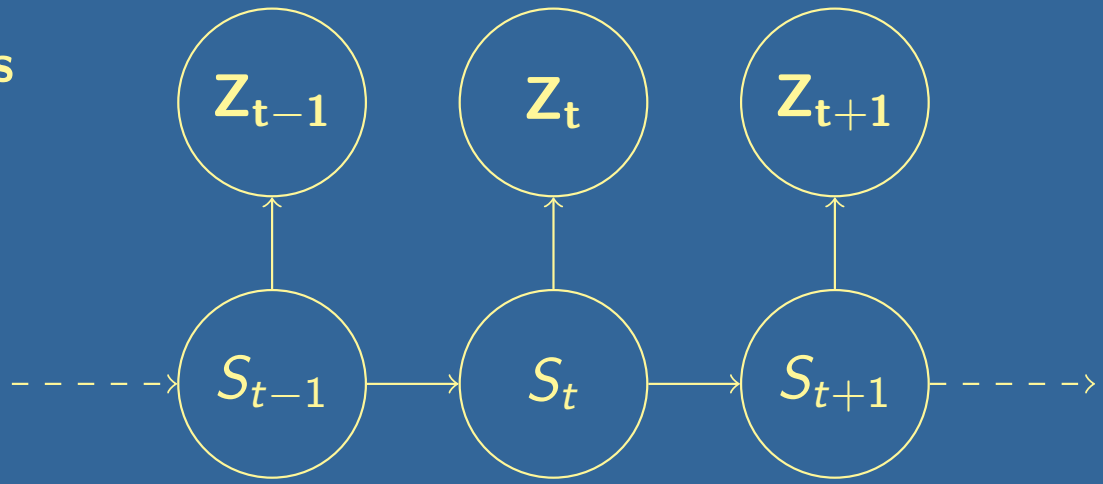
## What are Hidden Markov Models?

$\Rightarrow$ You assume a relationship between

1. the observations and unobserved "states" (most likely state)
2. the sequence of states (transition probabilities)

**state-dependent process**
(observed)

**state process**
(hidden)



# Analysing movement data with HMMs

## What are Hidden Markov Models?

$\Rightarrow$ State process takes finite possible values, $1, \ldots, S$

$\Rightarrow$ Value of $S_t$ selects which of $S$ component distributions generates observations $Z_t$

**state-dependent process**
(observed)

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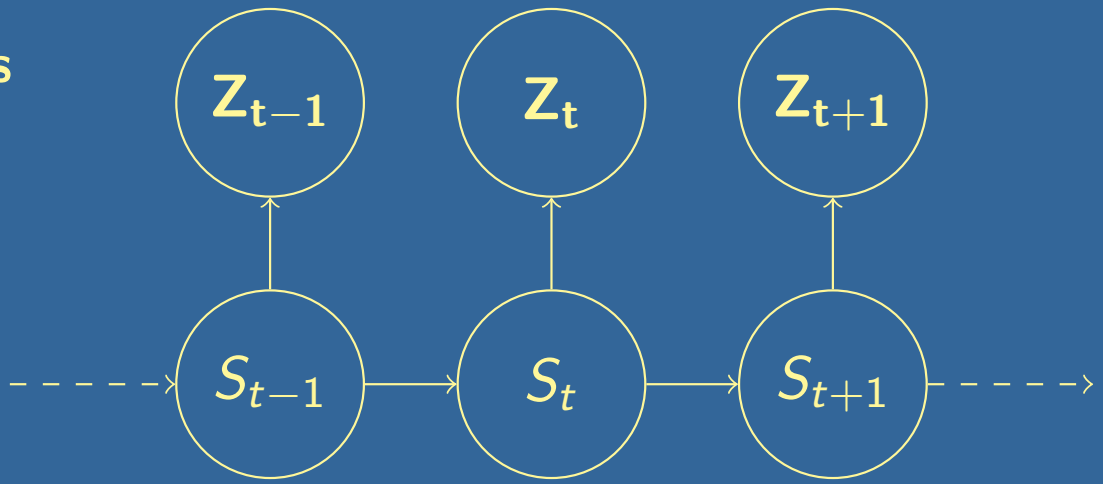

# Analysing movement data with HMMs

## What are Hidden Markov Models?

$\Rightarrow$ The distribution that generates an observation depends on the state of the underlying and unobserved Markov process [1]

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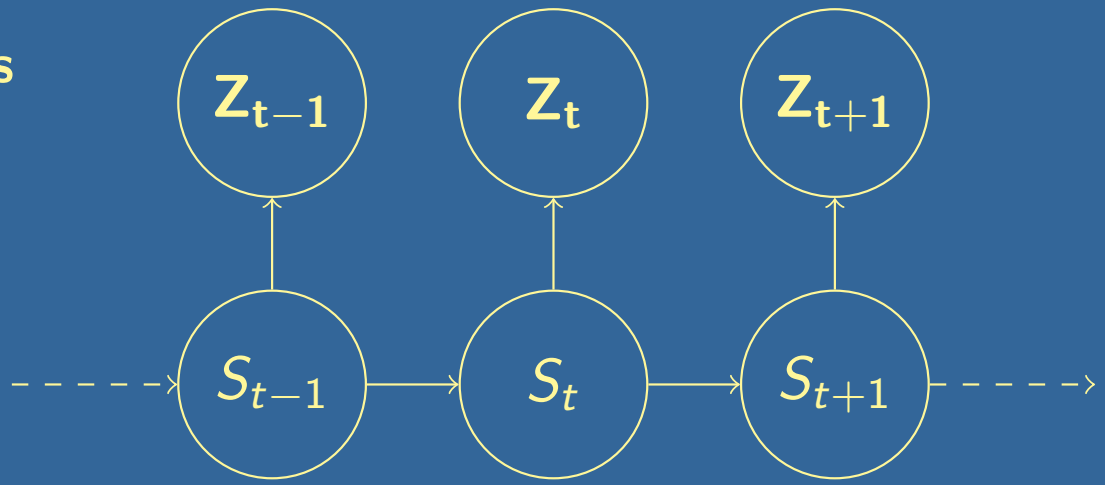



[1] Zucchini, MacDonald and Langrock 2016, HMMs for Times Series

# 2-state HMM: observation-generating process

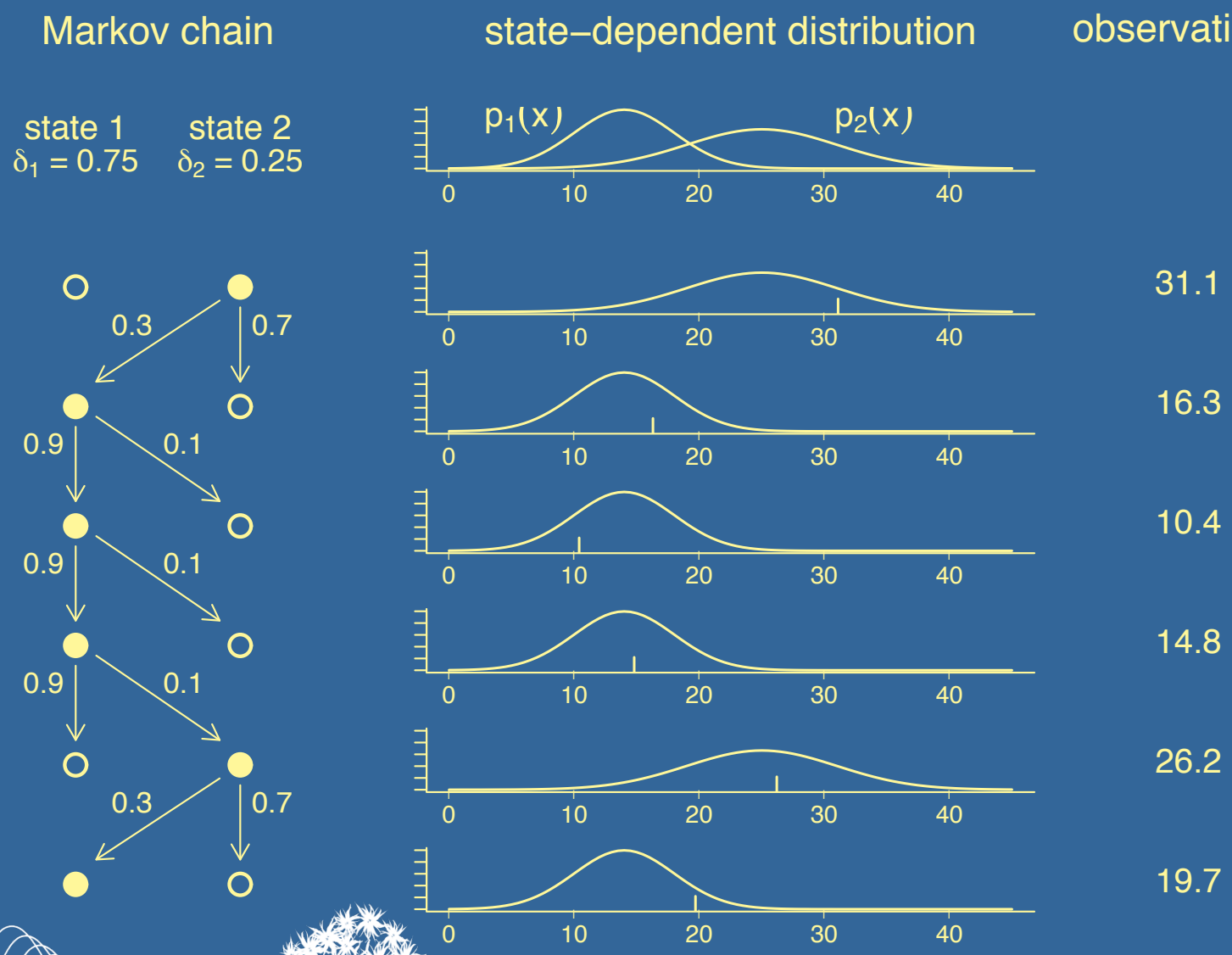



Figure 2.3, page 31, Zucchini, MacDoland and Langrock 2016

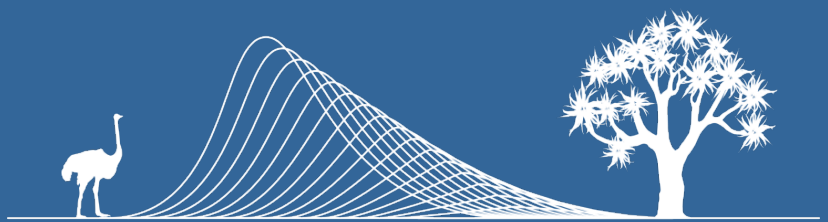
# Analysing movement data with HMMs

## Why are they useful?

$\Rightarrow$ Serial dependence naturally accounted for because the sequence of states is a Markov chain

$\Rightarrow$ It is characterised by the Markov property

- Conditional on the current state, the future is independent of the past





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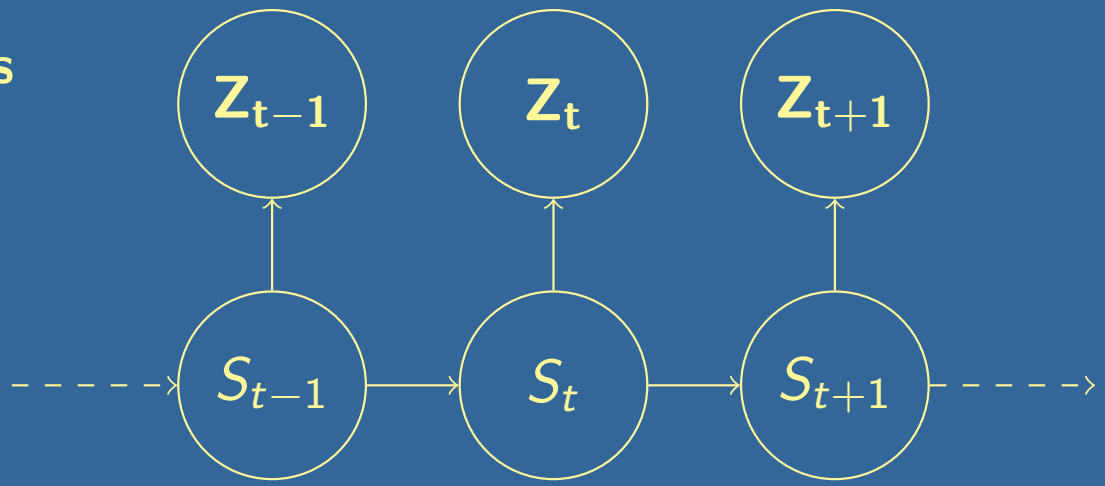

# Haggis example

The wild haggis (*Haggis scoticus*)

The wild Haggis is a fictional animal that inhabits the Scottish Highlands.

It's left leg is longer than it's right leg.

Certain slopes are optimal for movement and outside of that movement becomes a challenge.

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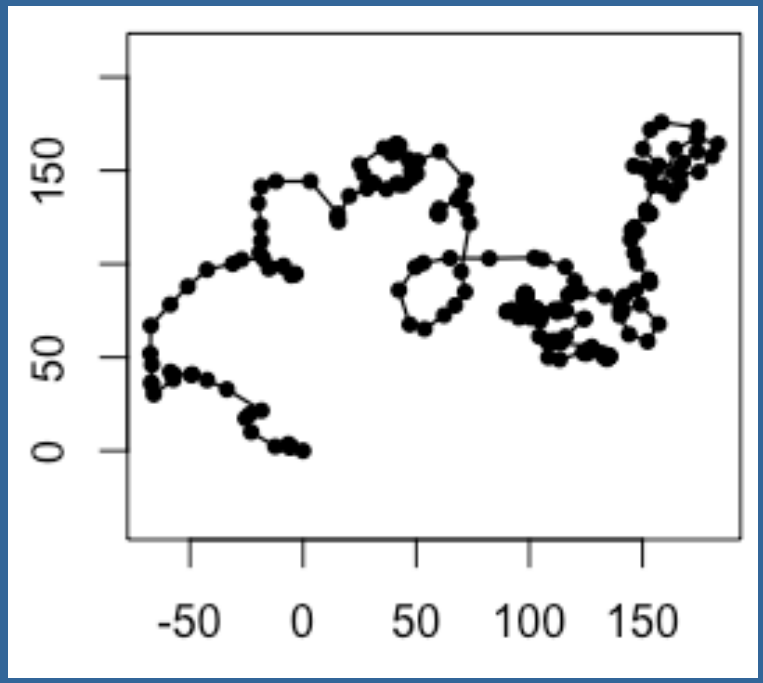


# Analysing movement data with HMMs

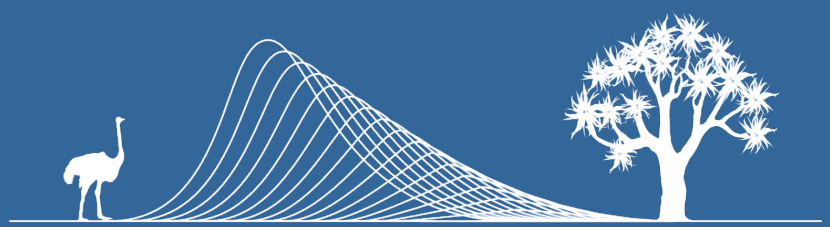
## What you can and cannot do with moveHMM

### Can

- ⇒ Fit a model to the step and turn distributions
- ⇒ Find the most likely state for each point
- ⇒ Carefully interpret states in a meaningful biological way
- ⇒ Find the effect of covariates on transition probabilities

### Cannot

- ⇒ Fit a model to irregularly sampled data
- ⇒ Assume that states correspond to behaviours
- ⇒ Assume the model is valid without checking it
- ⇒ Account for location uncertainty (but see `momentuHMM`)



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# HMM and movement ecology resources

## Groups

Link British Ecological Society Movement Ecology Special Interest Group

Link ecoHMM group Link AniMove

## Books

Link Hidden Markov Models for Time Series: An Introduction Using R, Second Edition. 2016. Walter Zucchini, Iain L. MacDonald, Roland Langrock

Link Animal Movement: Statistical Models for Telemetry Data. 2017. Mevin B. Hooten, Devin S. Johnson, Brett T. McClintock, Juan M. Morales

## Papers

Link Langrock et al. 2012. Flexible and practical modeling of animal telemetry data: hidden Markov models and extensions. Ecology 93(11): 2336–2342

Link Michelot et al. 2016. moveHMM: an R package for the statistical modelling of animal movement data using hidden Markov models. Methods in Ecology and Evolution 7(11): 1308–1315

Link McClintock 2017. Incorporating Telemetry Error into Hidden Markov Models of Animal Movement Using Multiple Imputation. JABES doi:10.1007/s13253-017-0285-6

Link Towner et al. 2016. Sex-specific and individual preferences for hunting strategies in white sharks. Functional Ecology 30: 1397–1407

Link McKellar et al. 2015. Using mixed hidden Markov models to examine behavioral states in a cooperatively breeding bird. Behavioural Ecology 26(1): 148-157