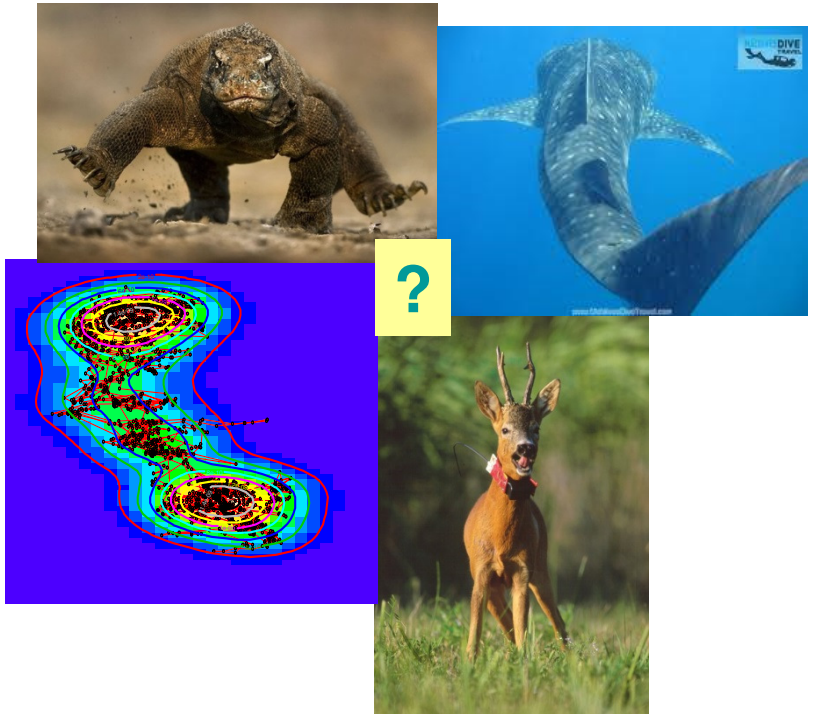
The ecology of animal movements: spatiotemporal scales, methods, inferences.



Swansea University
Prifysgol Abertawe

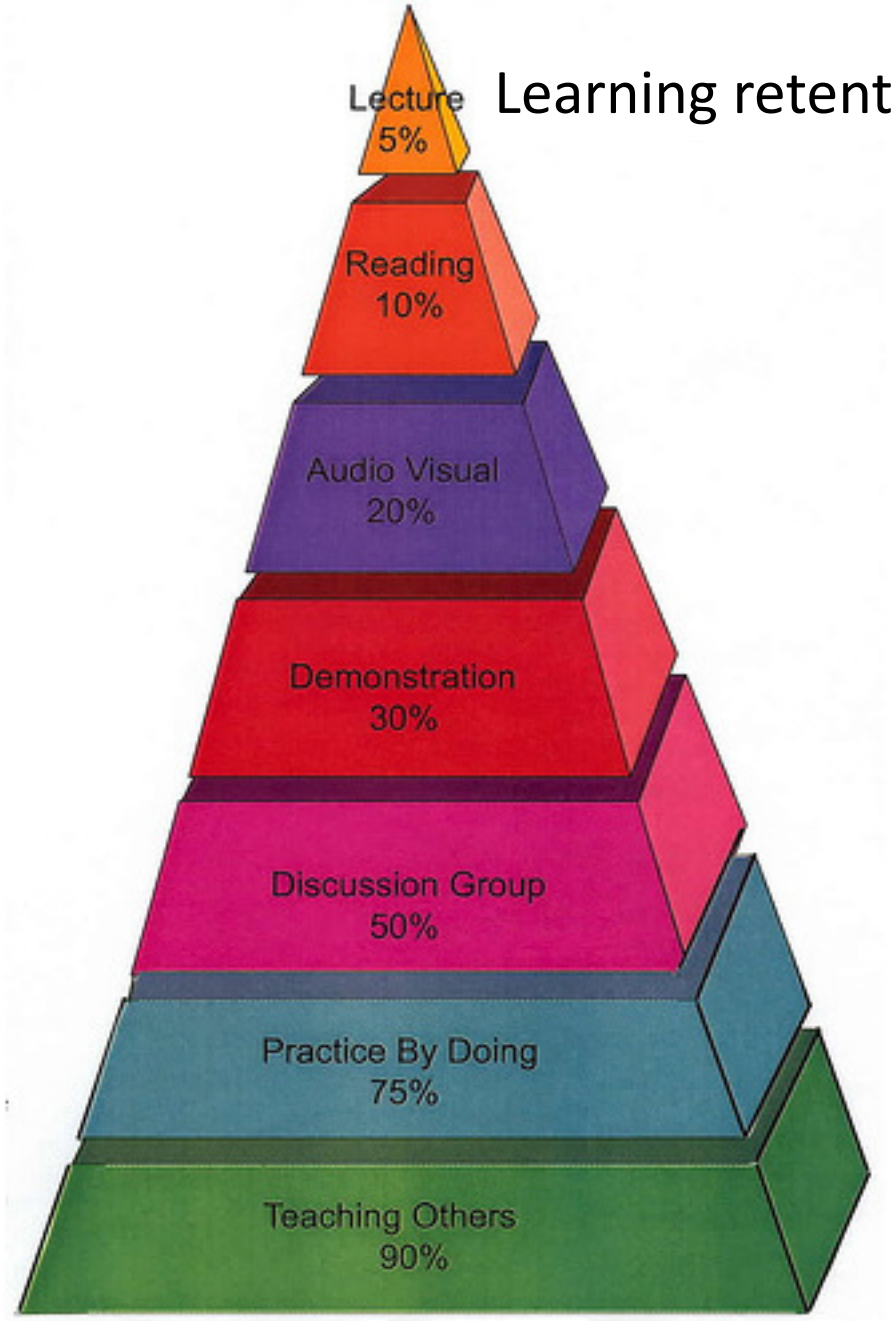
Luca Börger (@lucaborger)
Movement Ecology Workshop
UNESP Rio Claro, 19 March 2018

College of Science
Coleg Gwyddoniaeth

Lectures "represent a conception of education in which teachers who know give knowledge to students who do not and are, therefore, supposed to have nothing worth contributing.“

Bligh, in *What's the Use of Lectures?*
Wikipedia

Learning retention rates



Lecture 5%

Reading 10%

Audio visual 20%

Demonstration 30%

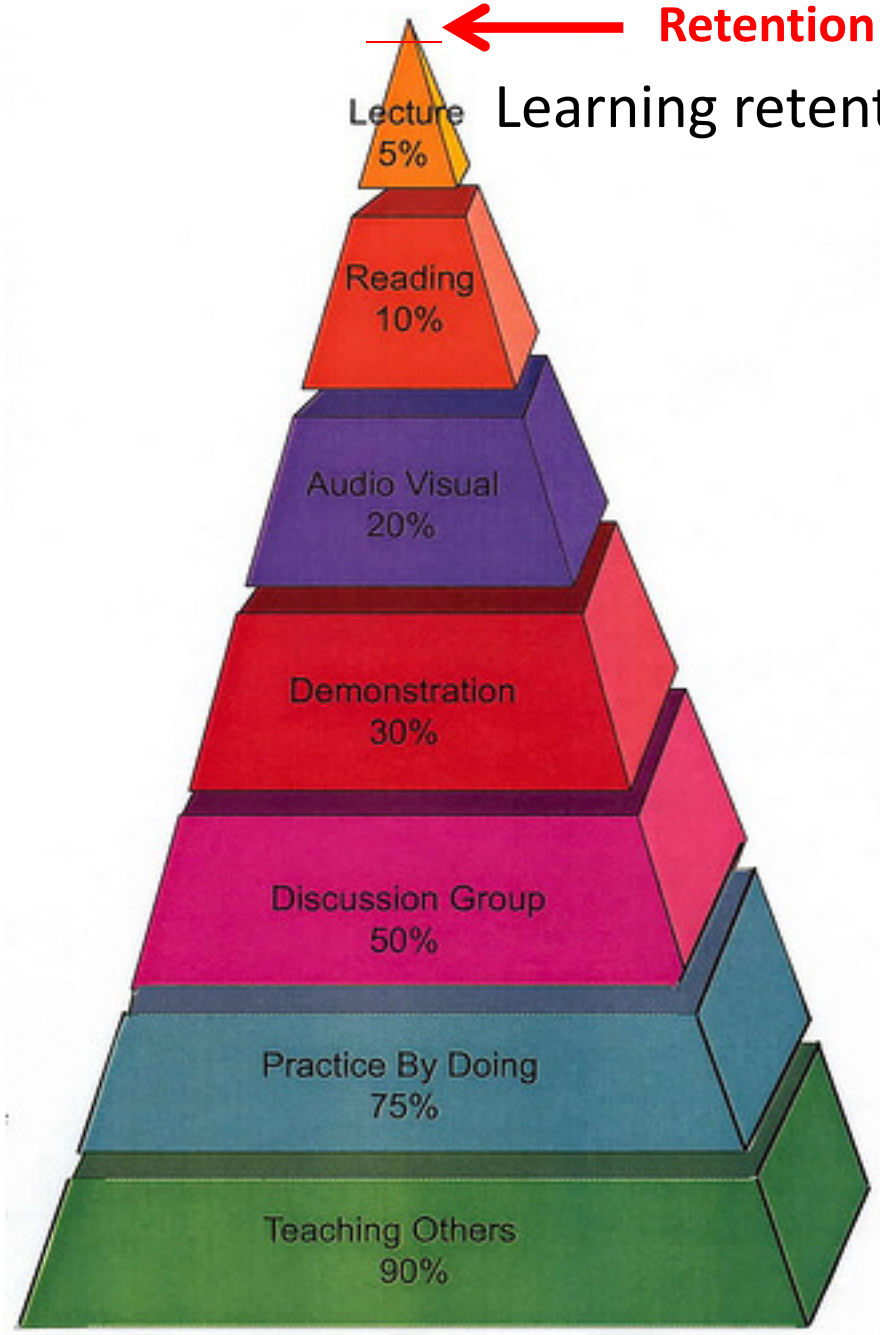
Discussion group 50%

Practice by doing 75%

Teaching others 90%

Retention rate when your laptop is on: 0.5%

Learning retention rates



Lecture 5%

Reading 10%

Audio visual 20%

Demonstration 30%

Discussion group 50%

Practice by doing 75%

Teaching others 90%

1. Close all laptops.

2. Switch mobiles off.

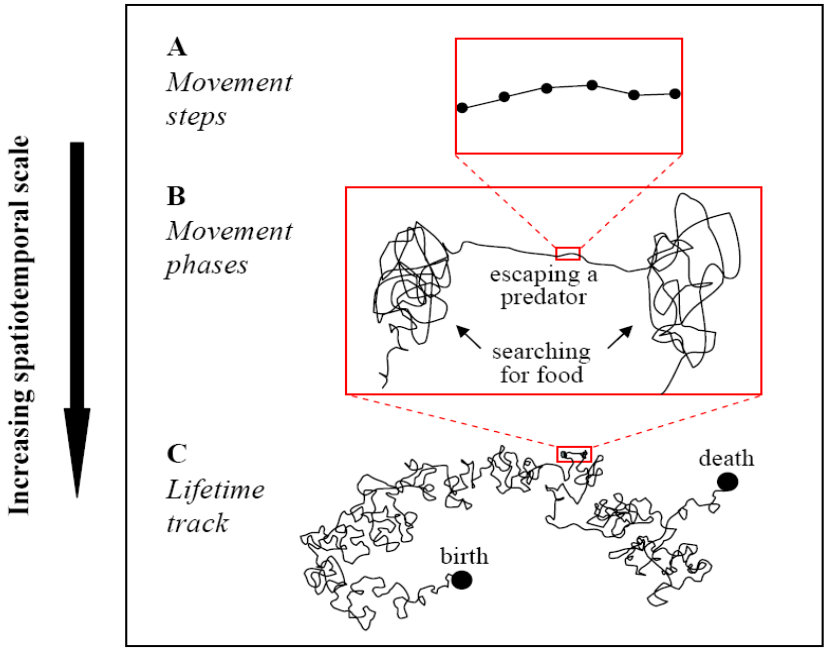
3. No tweeting etc.

4. There is no such thing as a ‘stupid question’ – ask anytime!

5. If you think we are wrong, or anyway you disagree, start a discussion – this is when science becomes interesting ☺

Definition of movement

Movement
A change in the spatial location of the whole individual over time.



Scales of movement:

Movement step
A single displacement of the entire body of an organism.

Lifetime track
The complete sequence of steps of an individual from birth to death.

Nathan et al. (2008) PNAS 105 (49)

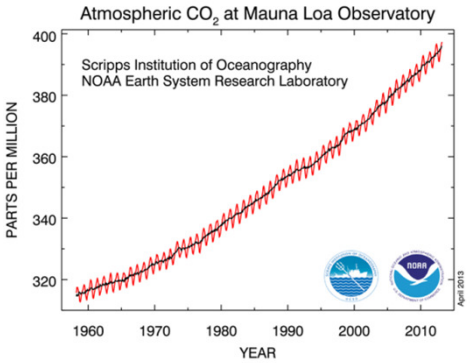
Importance of movement

Nature **269**, 578 - 581 (13 October 1977)

Dispersal in stable habitats

W. D. HAMILTON* & ROBERT M. MAY†

"…adaptations for achieving dispersal retain great importance even in uniform and predictable environments. "



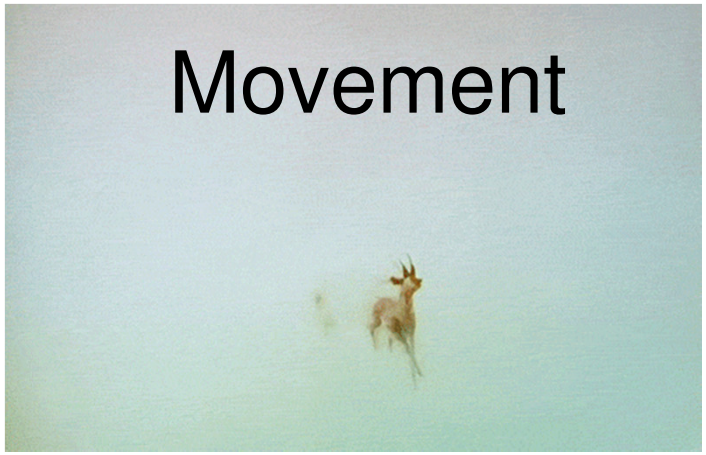
environmental change

BIOLOGICAL REVIEWS
Cambridge Philosophical Society
Biol. Rev. (2010), pp. 000–000.
doi: 10.1111/j.1469-185X.2010.00164.x

Behavioural responses to human-induced environmental change

Ulla Tuomainen and Ulrika Candolin*
Department of Biosciences, University of Helsinki, P.O. Box 65, FI-00014 Helsinki, Finland

(*Received 6 May 2010; revised 1 October 2010; accepted 15 October 2010*)



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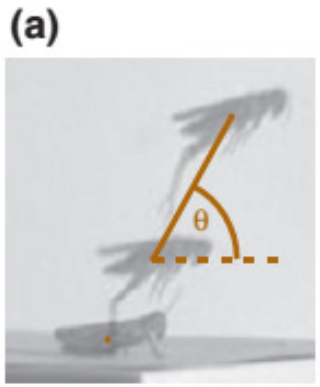
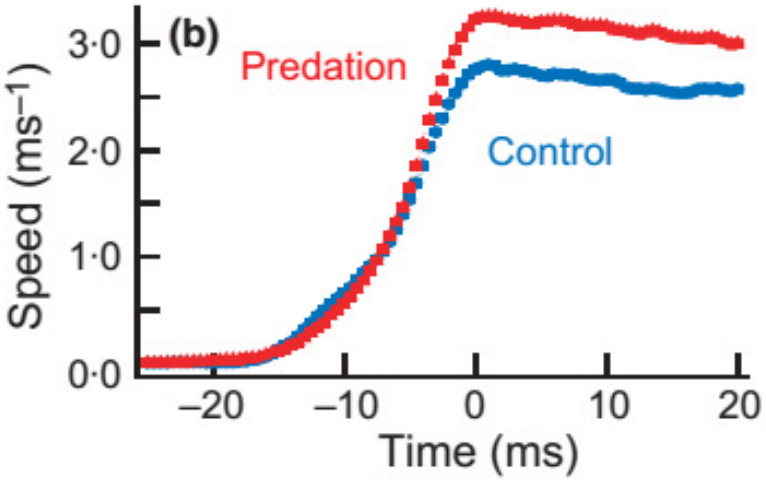
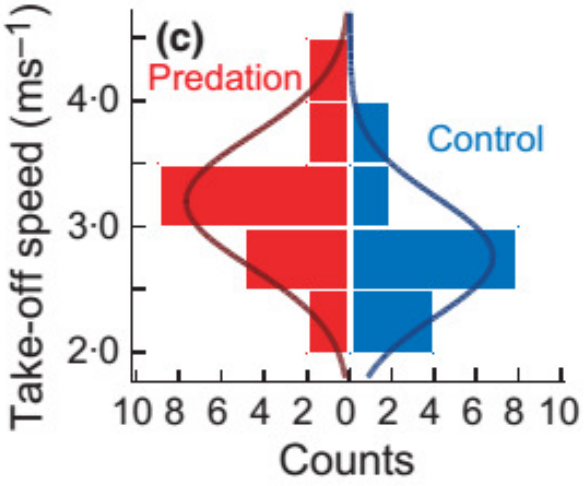
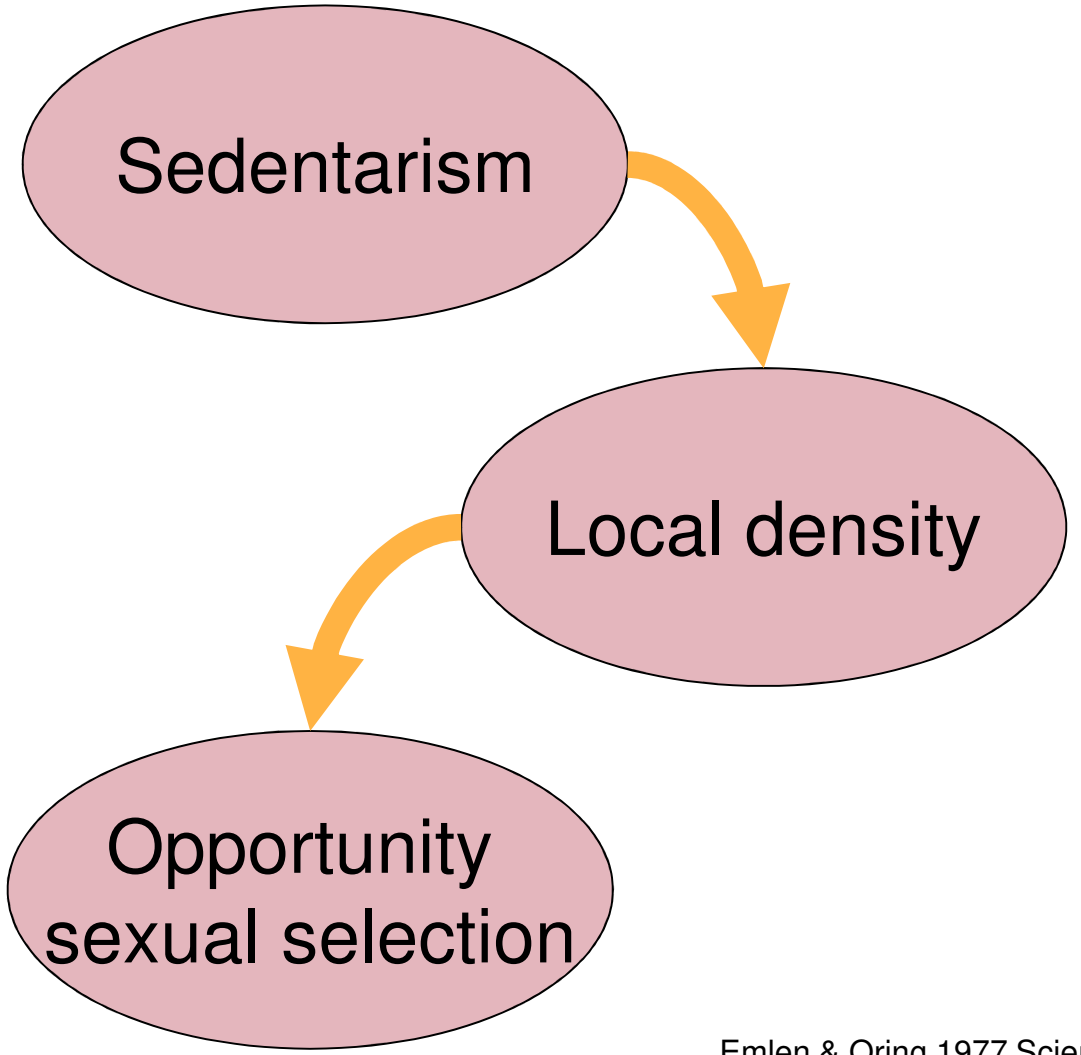






Hawlena & Schmitz (2011) Func. Ecol.

Consequences of home range movements
→ Biotic interactions

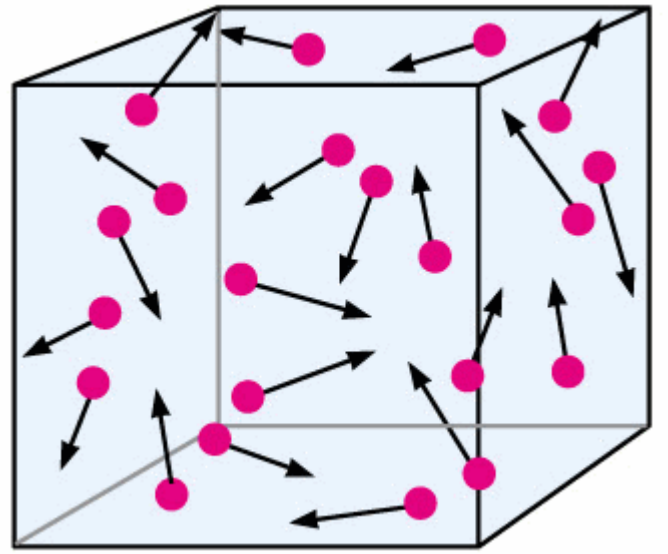


Emlen & Oring 1977 Science
Shuster & Wade 2003 PUP

Including movement into more realistic ecological models

Random movement

Traditional ecological models

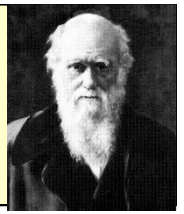


Identical individuals

Morales et al. (2010) Phil. Trans. R. Soc. B

Charles Darwin
The origin of species
6th ed. ch. 4 p.72

Movements – why bother?
→ *Evolution*

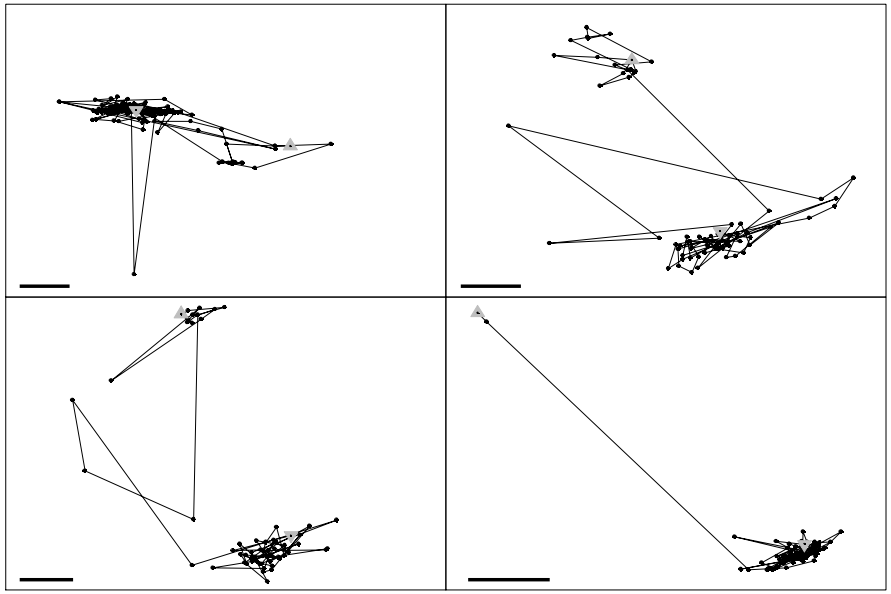


"but it may be here remarked that most animals and plants keep to their proper homes, and do not needlessly wander about; we see this even with migratory birds, which almost always return to the same spot.

Consequently each newly-formed variety would generally be at first local, as seems to be the common rule with varieties in a state of nature; so that similarly modified individuals would soon exist in a small body together, and would often breed together.

If the new variety were successful in its battle for life, it would slowly spread from a central district, competing with and conquering the unchanged individuals on the margins of an ever-increasing circle."

The wider context
Animal movement modes & the movement path



Home range

Migration

Dispersal

Nomadism

Multiscale

Behaviour

CHAPTER 8

Migration quantified: constructing models and linking them with data

Luca Börger, Jason Matthiopoulos, Ricardo M. Holdo, Juan M. Morales, Iain Couzin, and Edward McCauley

In many cases, the daily movements of animals represent in miniature movements similar to migration, and require similar mechanisms of operation.

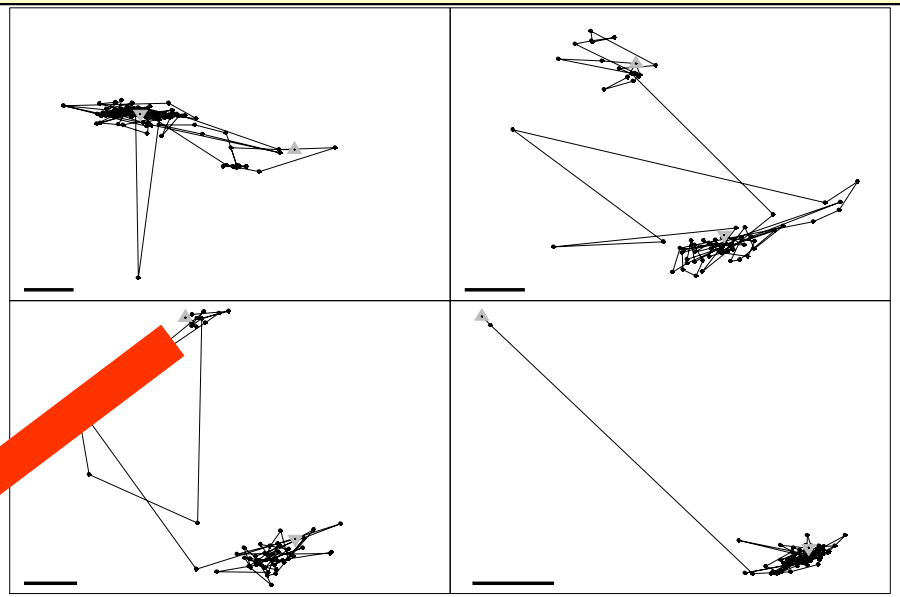
Woodbury (1941)

(. . .) we now probably see more clearly than ever before the intimate relation existing between the animals and the conditions which influence their migrations.

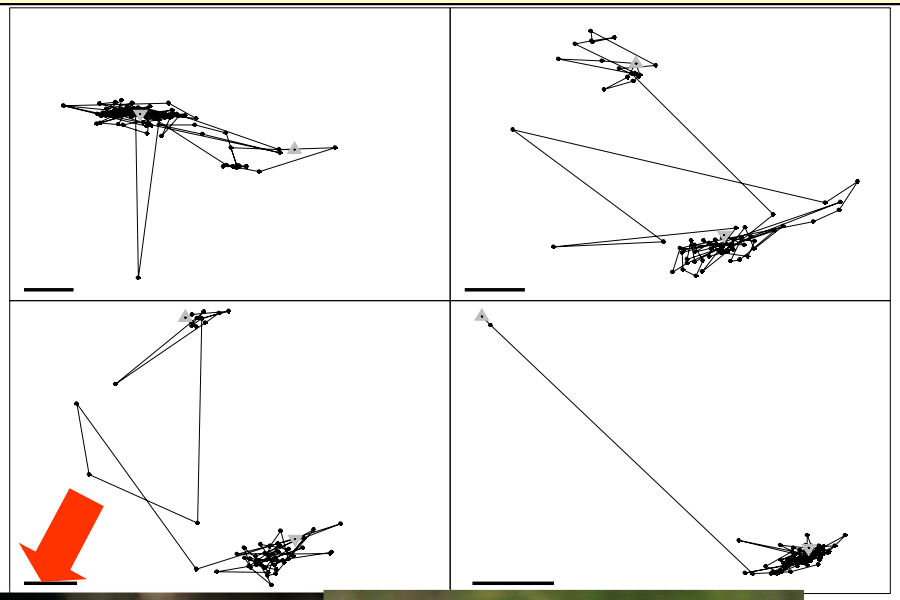
Adams (1918)

Oxford Univ. Press (2011)

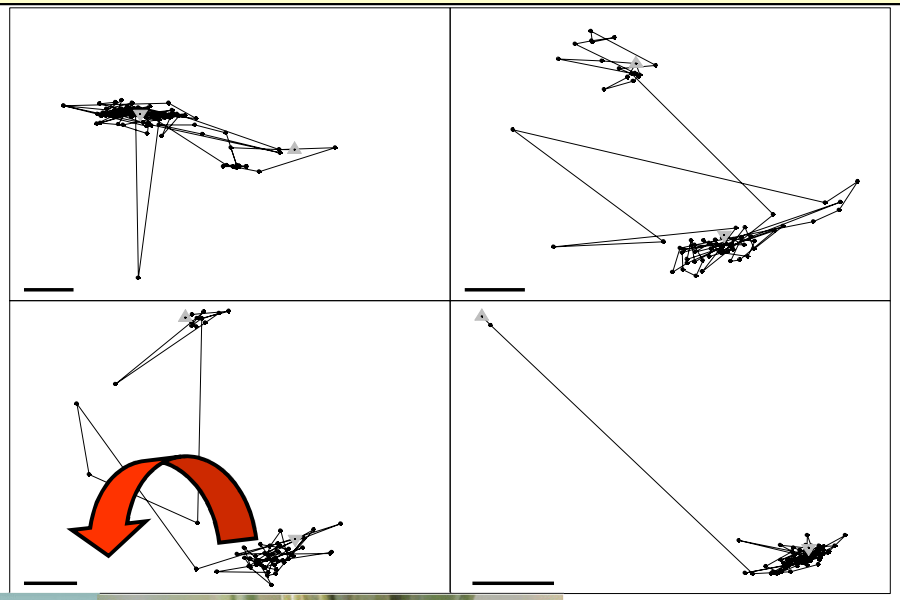
Concepts:
The movement path → behaviour?



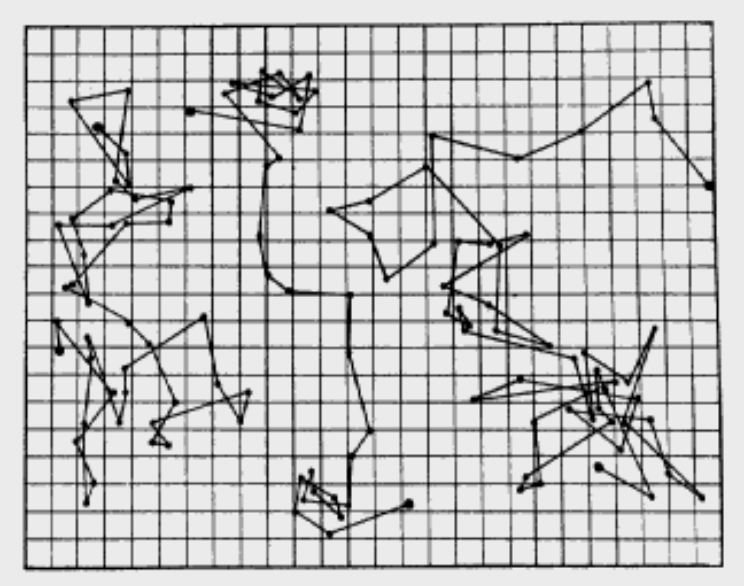
Concepts:
The movement path → behaviour?



Concepts:
The movement path → behaviour?

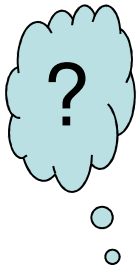


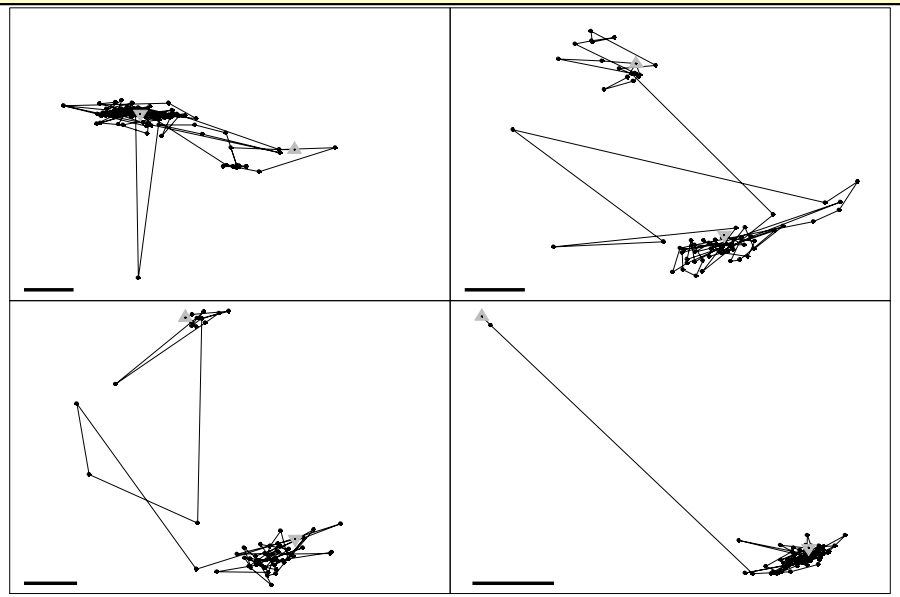
Concepts:
The movement path → behaviour?



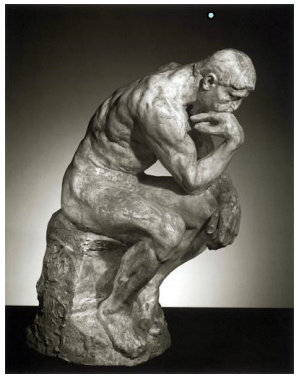
Brownian motion

J.B. Perrin 1926
R. Brown 1827



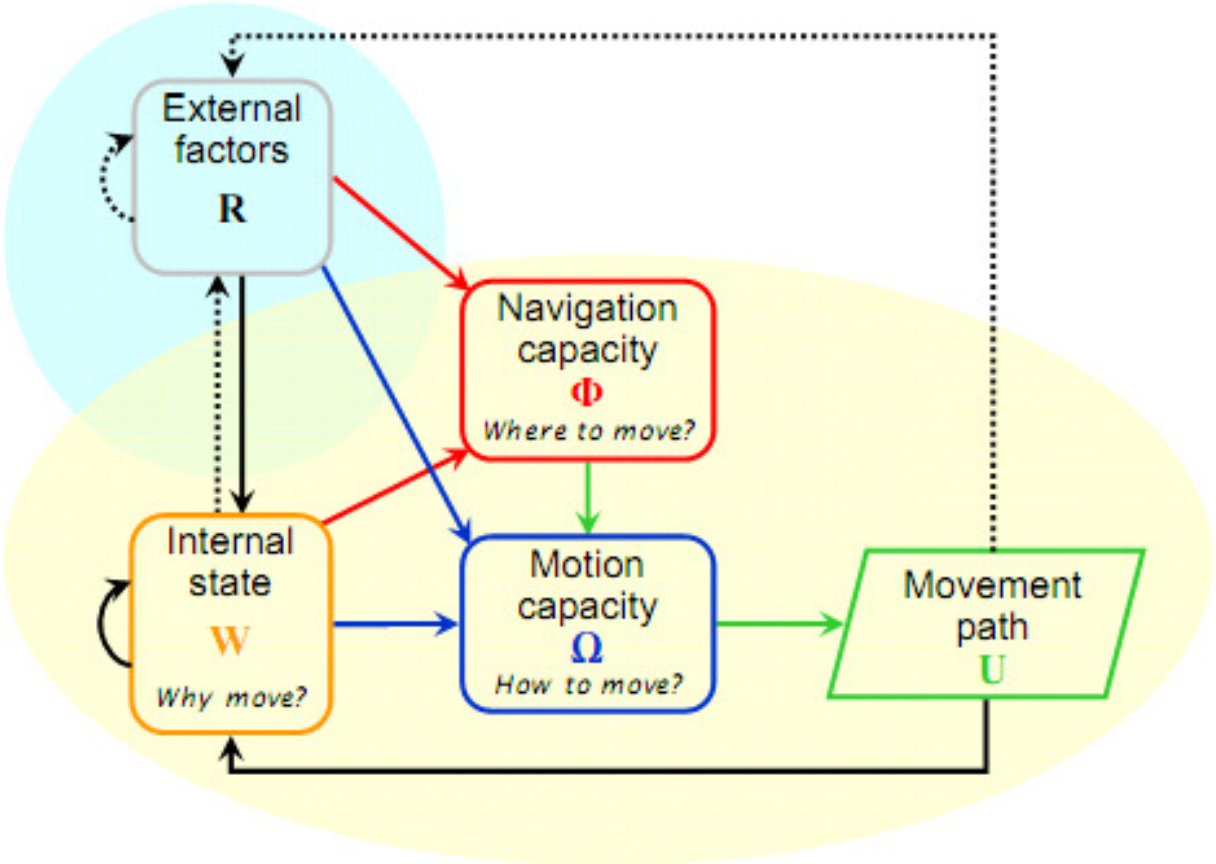


Elk movement

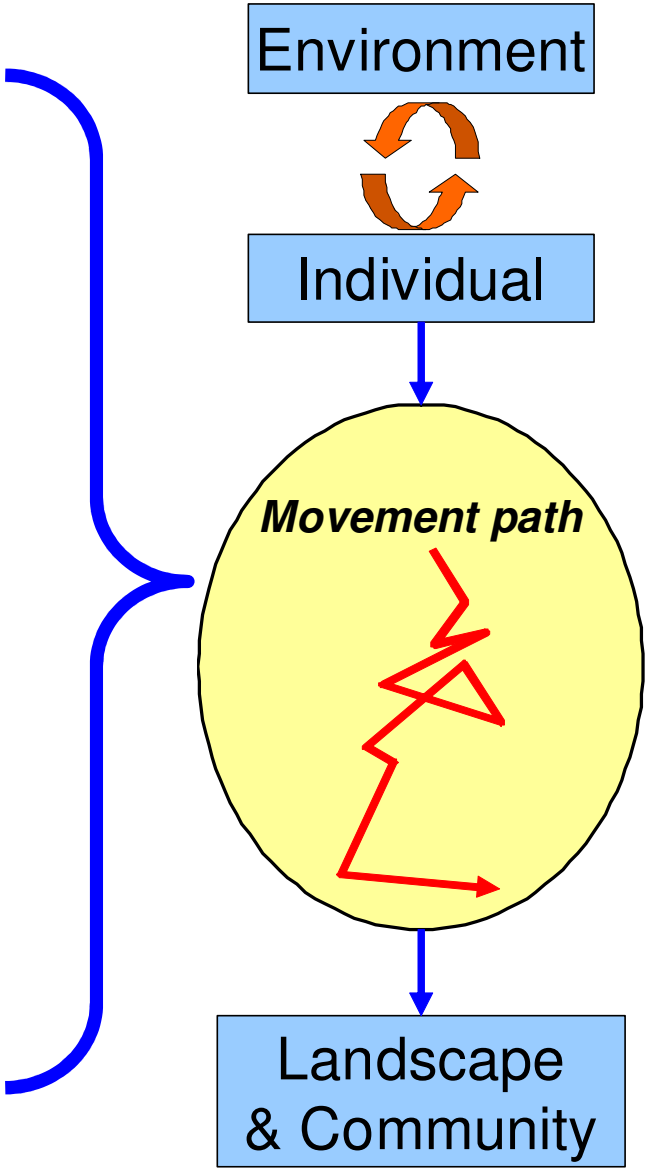


Purely stochastic processes can lead to the emergence of distinct spatial patterns in movement paths

Movement Ecology
→ unified modelling framework



$$\mathbf{u}_{t+1} = F(\Omega, \Phi, \mathbf{r}_t, \mathbf{w}_t, \mathbf{u}_t)$$



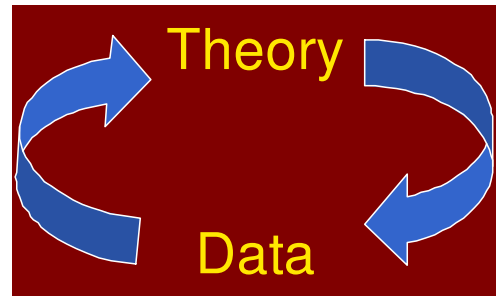
Nathan et al. 2008 PNAS; Fryxell, Börger et al;. 2008 PNAS

Is Science Mostly Driven by Ideas or by Tools?

Dyson (2012) Science 338: 1426

… both are going strong!

- Biologging/Telemetry
- Computing power



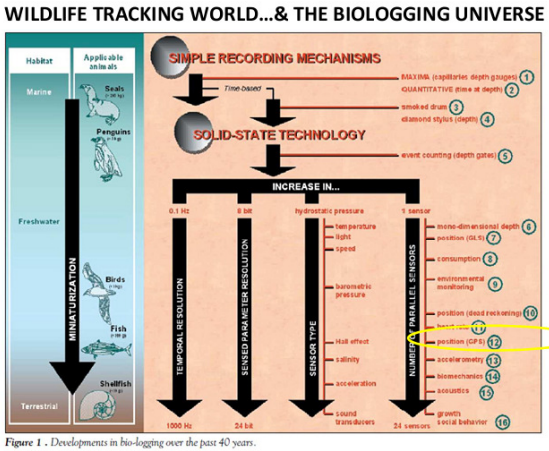
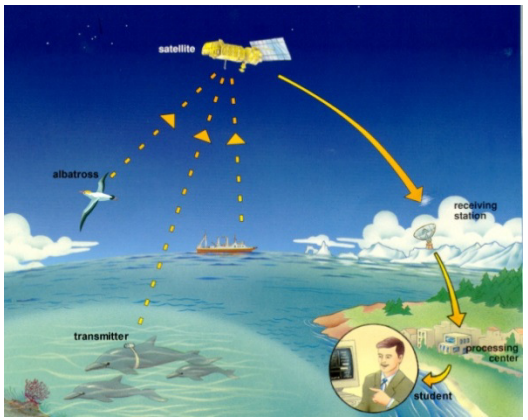
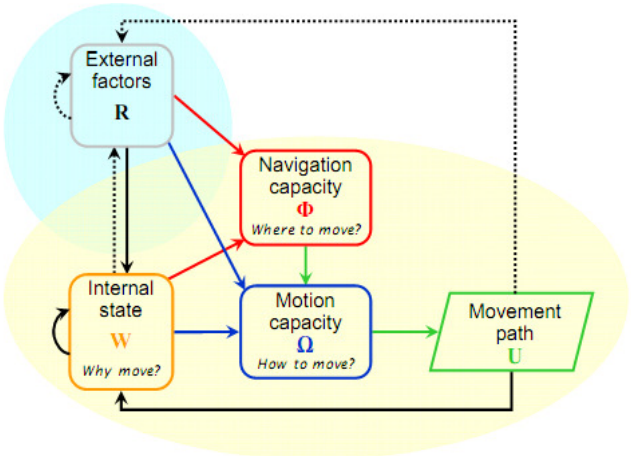


Figure 1 . Developments in bio-logging over the past 40 years.

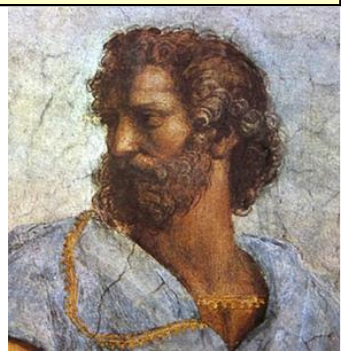


Movement ecology framework



$$\mathbf{u}_{t+1} = F(\Omega, \Phi, \mathbf{r}_t, \mathbf{w}_t, \mathbf{u}_t)$$

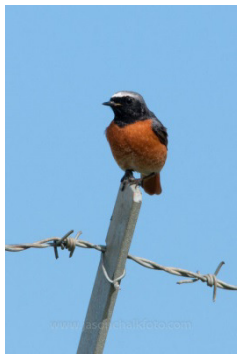
Movements
→ interesting, but difficult to study



"*Now we must consider in general the common reason for moving with any movement whatever*"
(Aristotle, De Motu Animalium, 4th century BC)

Question: what happens to migratory birds in winter?

1. Transmutation

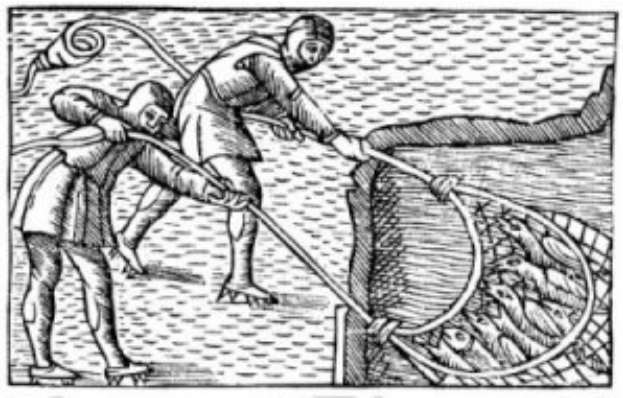


Redstart

Robin

2. 'Migration'

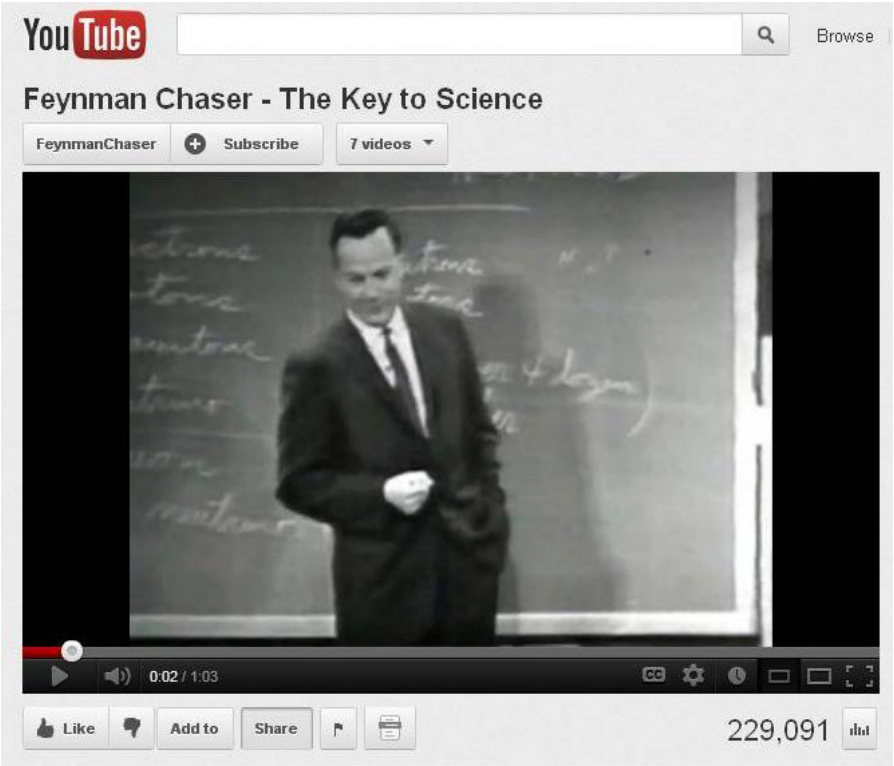
3. Hibernation



Plausible with some observations, but then taken as fact for centuries

Key to the scientific method

Guessing is fine, but then there is a crucial part …



1. New theory → guess
2. Compute the consequences
3. Compare to nature
4. Reject if not supported (!)

Fundamental also for movement research

Question-driven approach

Step 1: Elicit research questions.

Step 2: Translate questions and hypotheses into quantifiables (statistical models and parameters).

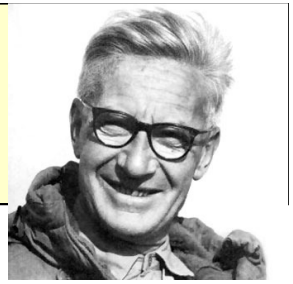
Step 3: Determine study design and analysis strategy (→ Methods).

Step 4: Fit models to movement data.

Step 5: Evaluate model fit and derive inferences.

Fieberg & Börger (2012) J. Mammal.
Börger et al. (2011) Inferential approaches. Oxford U. Press

Niko Tinbergen's four questions: Movement = Behaviour

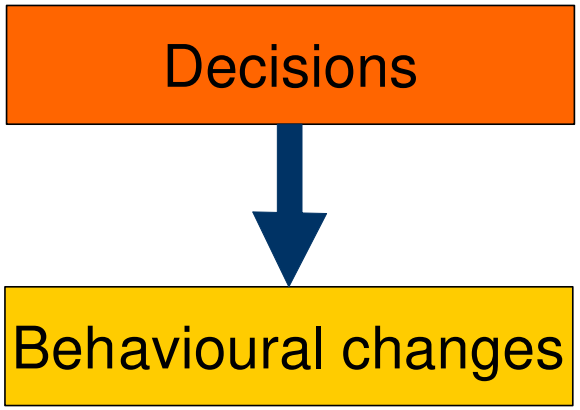


1. Why (how) did the animal respond with the behaviour? (Stimulus; Response)

2. Function & Fitness consequences

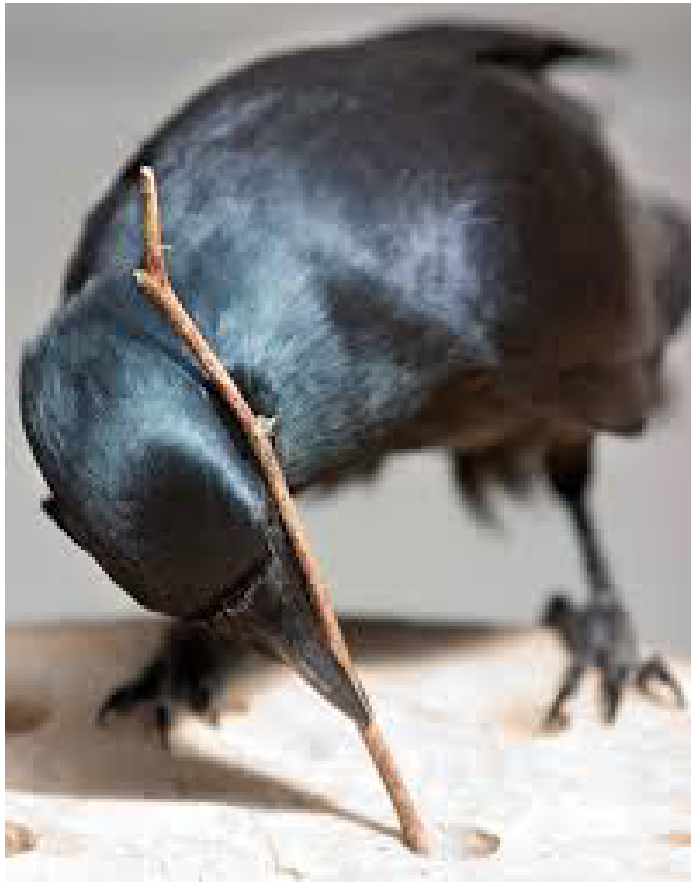
3. Development of behaviour (ontogeny)

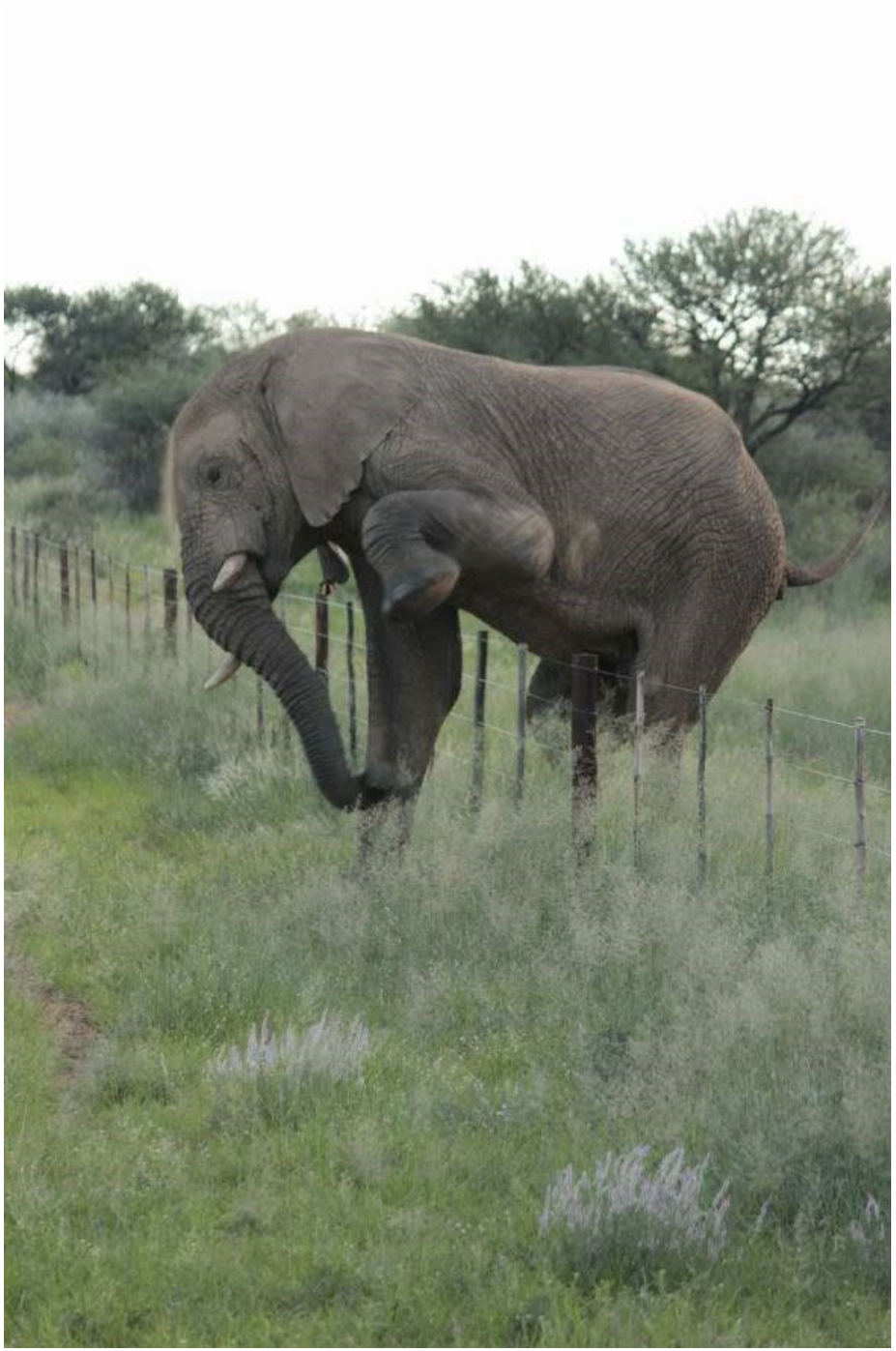
4. Evolution of behaviour



Why?

Why?

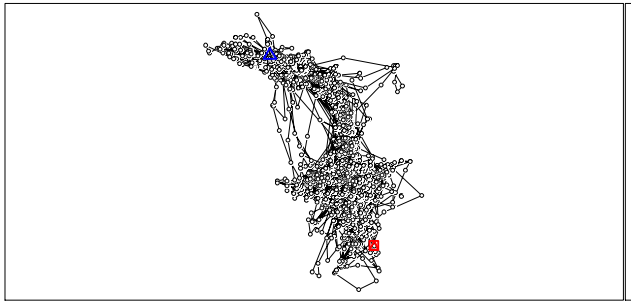




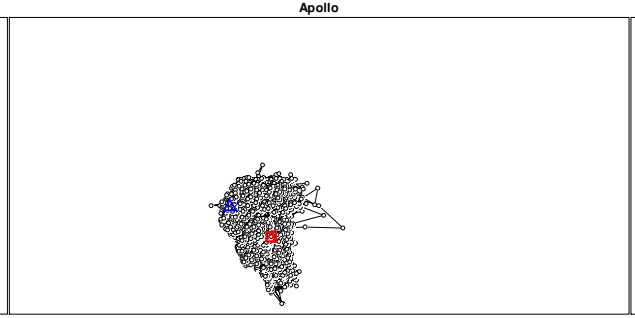

© John B. Weller

Movement paths

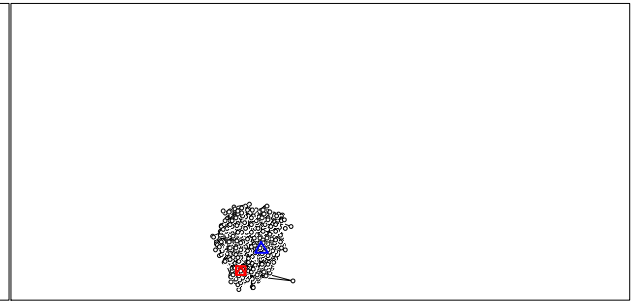
Ale



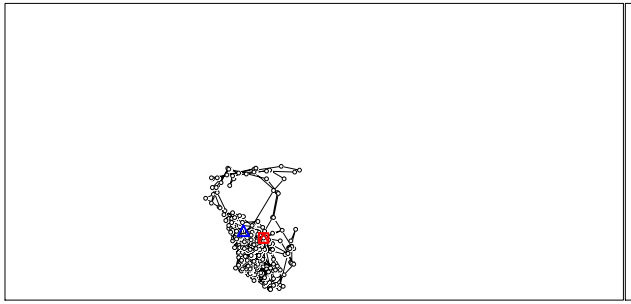
Apollo



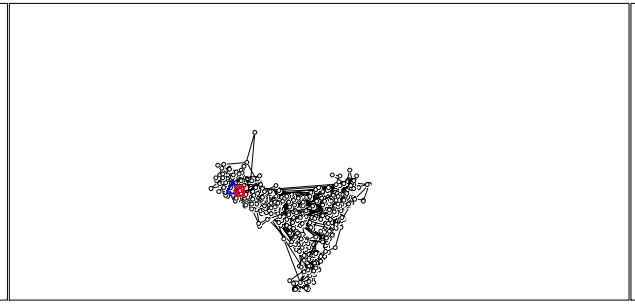
Athena



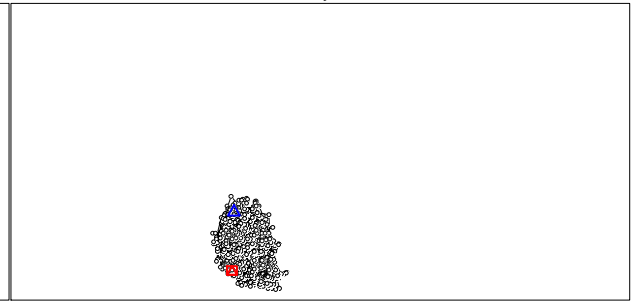
Ceres



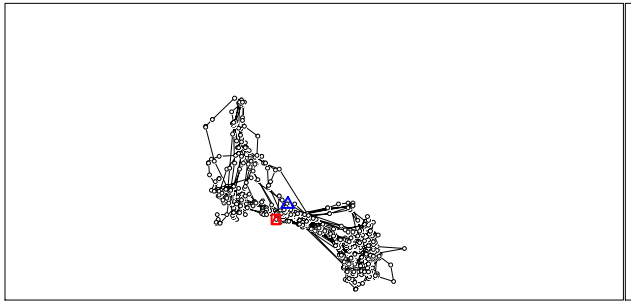
Fizz



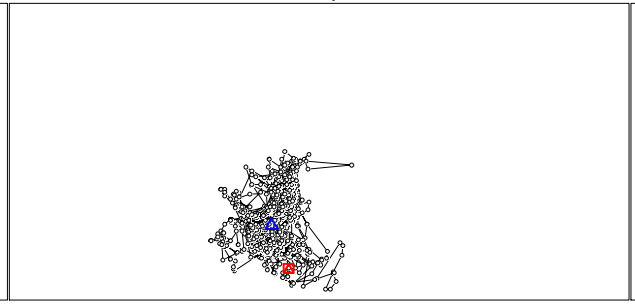
Fly



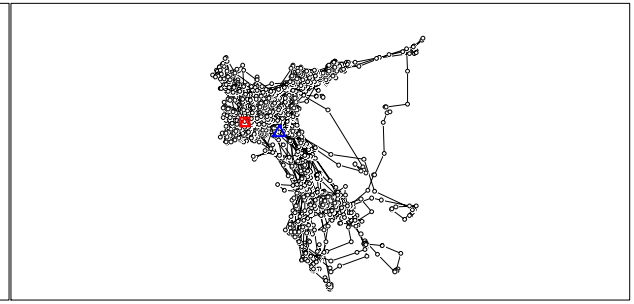
Poseidon



Sonny



Vera



CHAPTER 8

Migration quantified: constructing models and linking them with data

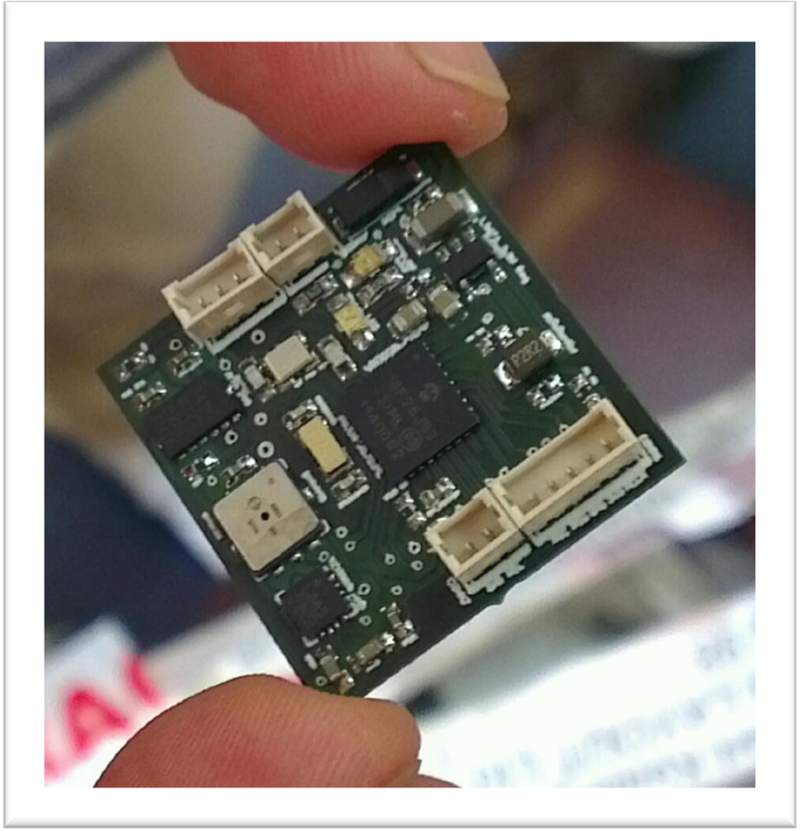
Luca Börger, Jason Matthiopoulos, Ricardo M. Holdo, Juan M. Morales, Iain Couzin, and Edward McCauley

"There are statistical difficulties in separating the effects of internal, environmental and conspecific influences from a set of [location] data"

the problem cannot be solved by increasing sample size but additional independent information is necessary

in: Millner-Gulland et al. 2011 OUP

Solution: Biologging Data

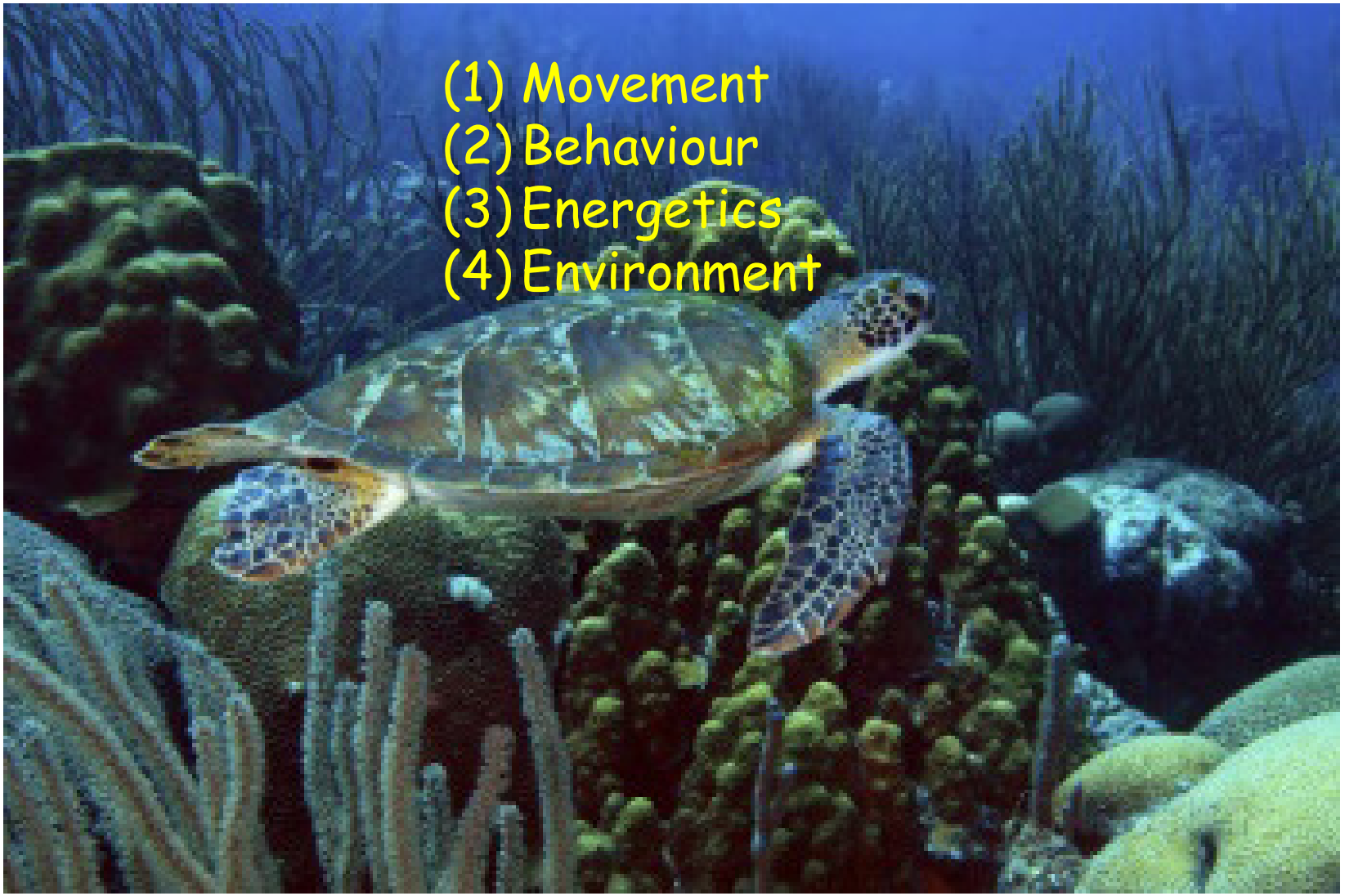


SLAM

Swansea Laboratory Animal Movement

So what can we do?

Key parameters;



Are animals free to move where-ever they want?

FOOD
!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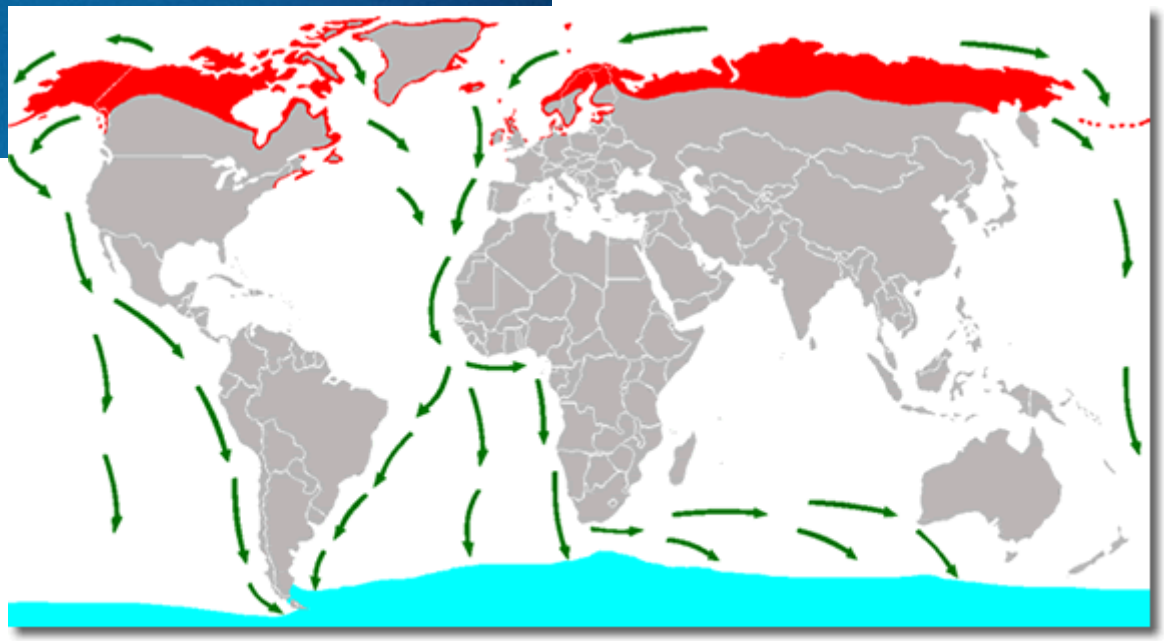
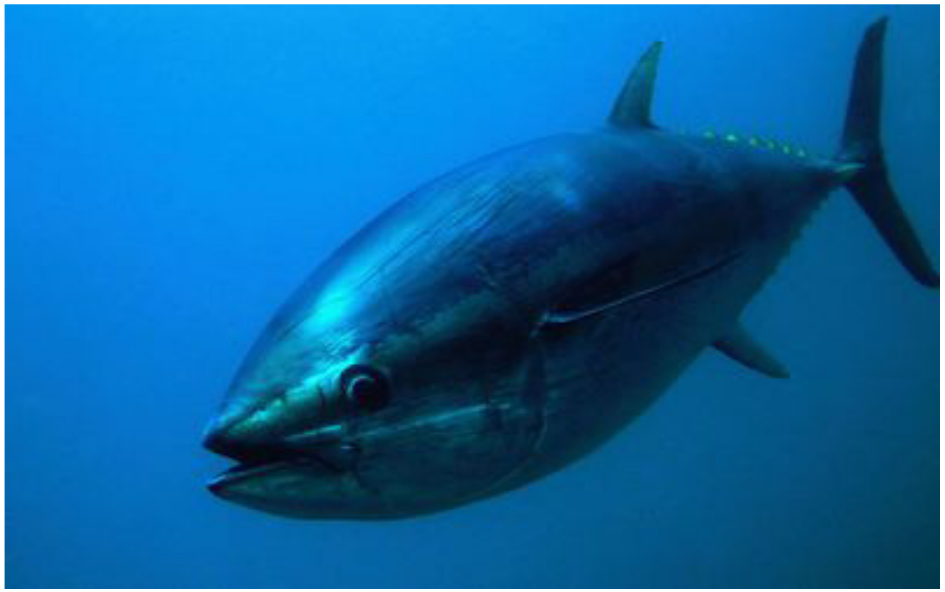
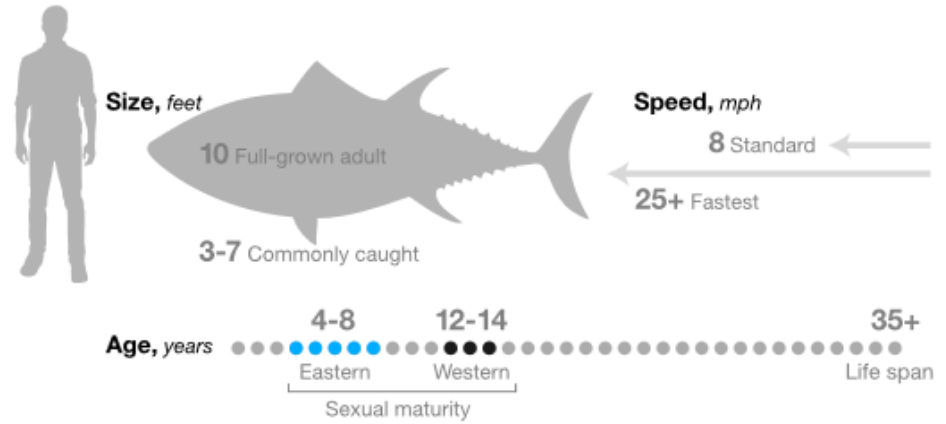
www.cesarpastor.com



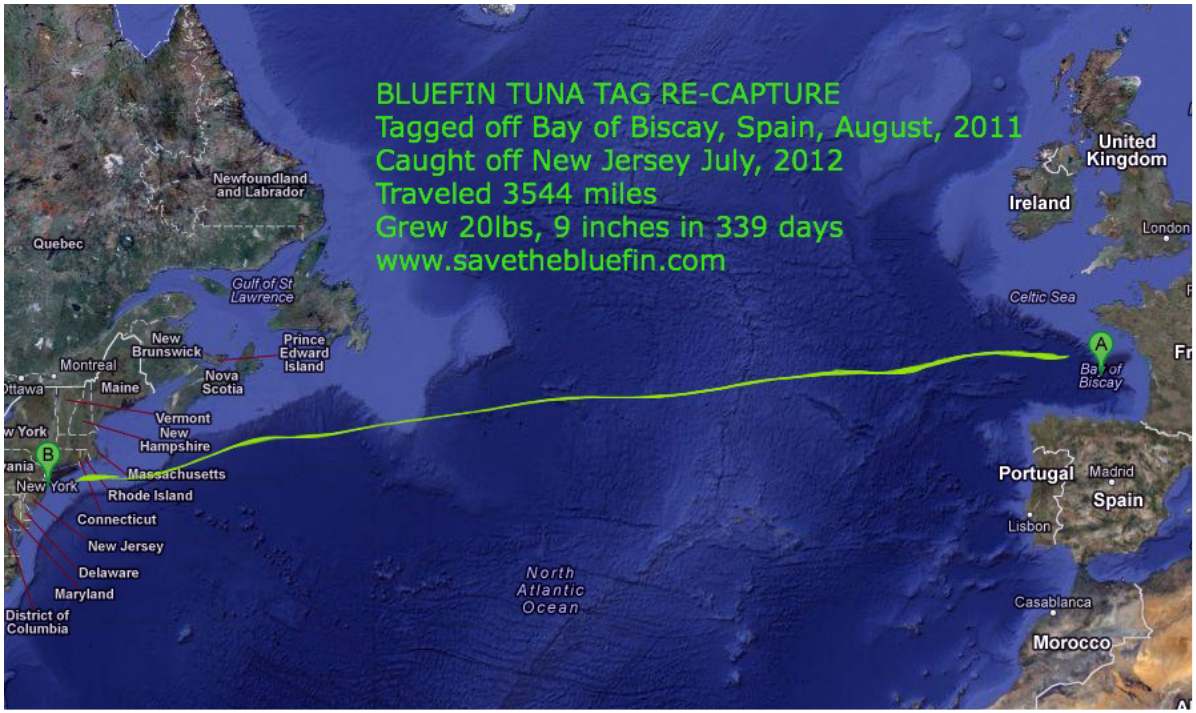
Arctic Tern
Sterna paradisaea

Distribution migration:
- red: breeding
- green: migration

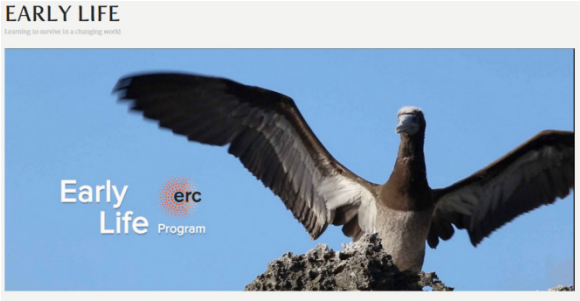


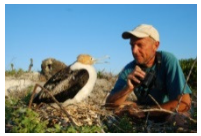


NGM ART. SOURCE: BARBARA BLOCK, STANFORD UNIVERSITY

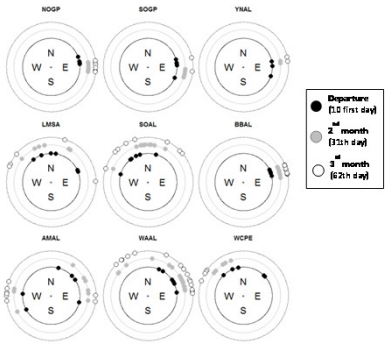


How do naïve juveniles navigate the environment?



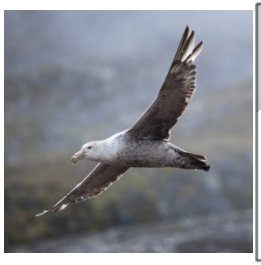


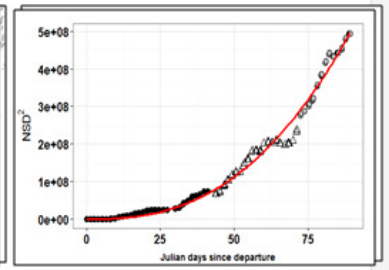
6 Albatross species
2 giant petrel species
1 petrel species
98 Argos-tracked 3 months



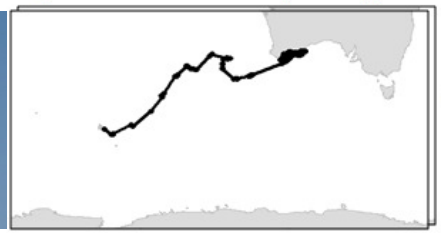
De Grissac et al. (2016)

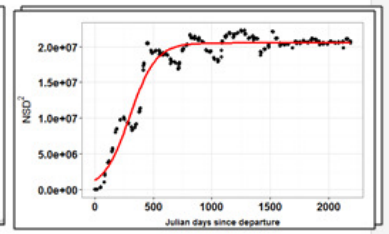
a) Northern giant petrel: nomadic type model



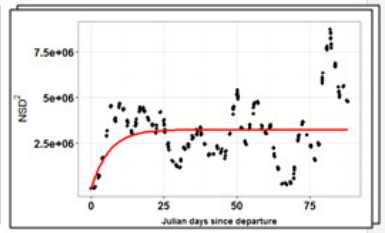


b) Black-browed albatross: dispersive type model

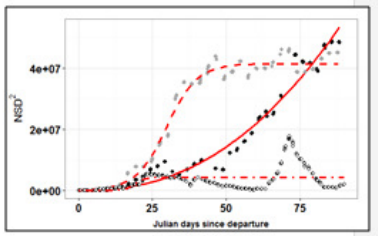




c) Sooty albatross: large-scale looping type fitted by home-range model.



d) Wandering albatross: 3 movements types fitted by nomad and dispersal models.



Learning outcomes

1. Define research questions

2. Translate questions and hypotheses into quantifiables (statistical/mathematical models and parameters).

3. Determine study design and analysis strategy (Methods).

4. Fit models to movement data or simulate data according to specified hypotheses.

5. Evaluate model fit and derive inferences.

6. Document the full workflow in a reproducible manner.

Monday 19th – Classes from 08:30 to 18:00
Module 1: Introduction to Movement Ecology & Course & R set up
Module 2: Movement path analysis I – steps and turns + data preparation

Tuesday 20th – Classes from 08:30 to 18:00
Module 3: Movement path analysis I – path segmentation
Module 4: Recap of statistical modelling (from LMs to GLMs to GAMs)

Wednesday 21st – Classes from 08:30 to 18:00
Module 6: Movement path analysis II – the squared displacement method and movement modes (foraging trips, home range, dispersal, migration, nomadism)
Module 7: Intro to hierarchical/mixed models for grouped data; Intro to nonlinear models

Thursday 22nd – Classes from 08:30 to 18:00
Module 7: Space use analysis – Home range estimation (2D & 3D) and quantification of individual interactions (static and dynamic approaches)

Friday 23rd – Classes from 08:30 to 18:00
Module 9: Habitat use and resource selection: from classical models to integrated step selection models
Module 10: Questions & application on your own data

All ears to your questions now … and at any time!