How do resource abundance and stochasticity affect animal movement?

Quantitative Ecology Lab
UBC Okanagan

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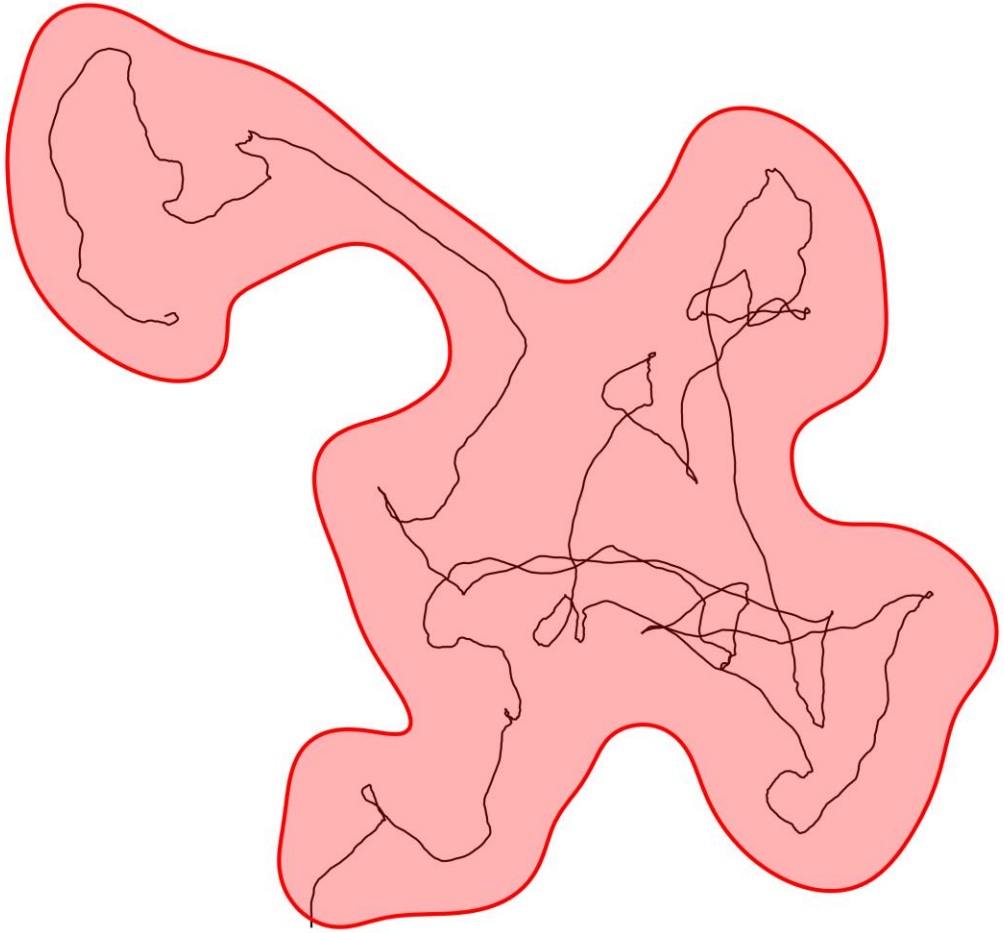
Causes of animal movement

- Searching for resources:
  - Food, nutrients (e.g., salt)
  - Water
  - New den/nest
  - Mate/group
- Escaping predators/competitors
- Defending resources/territory

<u>Can measure HR instead of individual needs</u>

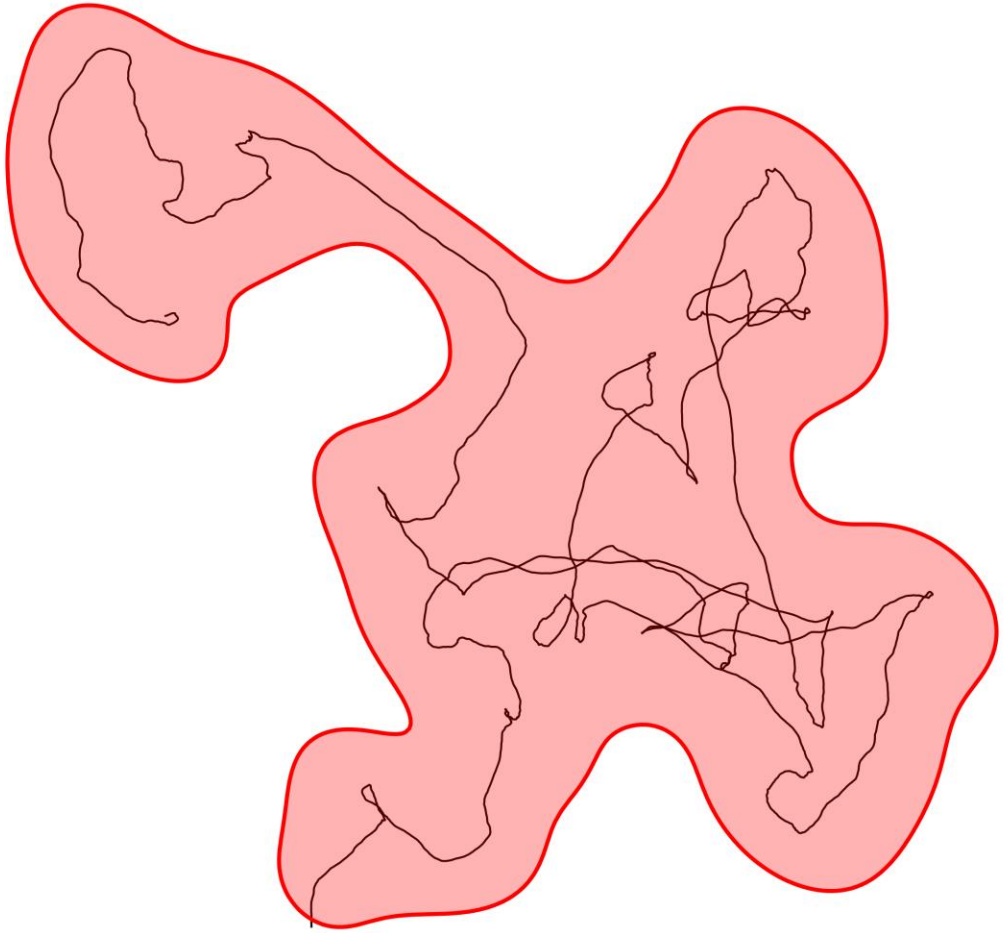
Defining home ranges

- Area required for essential needs
- Does not include exploration
- Animals must be range-resident
- HR must have a stable centroid
- Not applicable to:
  - Nomadic animals
  - Migrating animals



HR size depends on many factors

- HR ∝
  - Heterogeneity
  - Predation (?)
- HR ∝ 1/
  - Resource abundance
  - Resource predictability
  - Competition (?)
  - Connectivity (?)

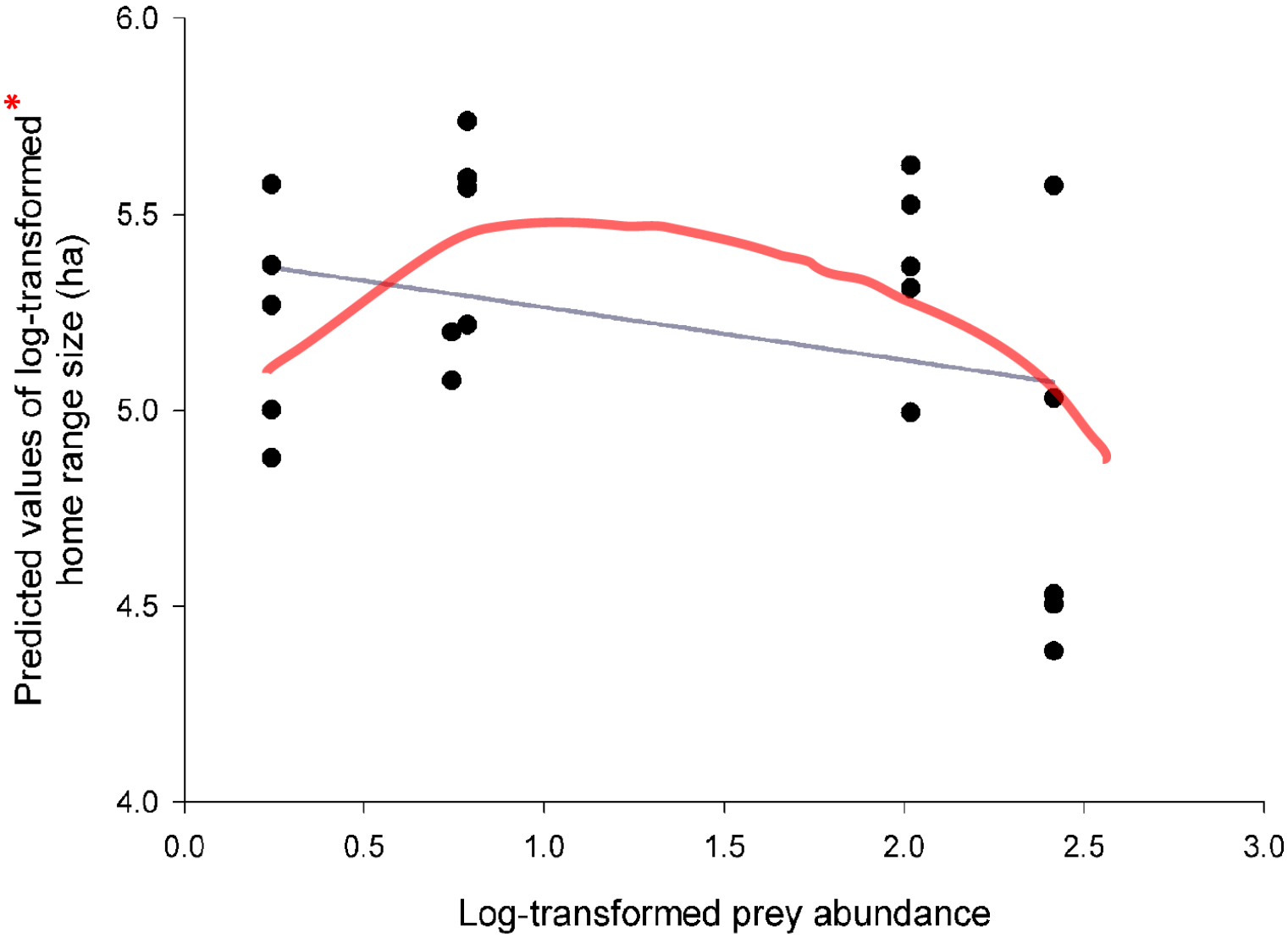


Defining resource abundance

- Resource abundance:
  - Depends on energetic needs (food, water, …)
  - Dens
  - Mates/conspecifics
  - Symbionts

- Can measure it using NDVI:
  - Only accounts for plant abundance (not diversity)
  - Ignores animal abundance (prey, competitors_
  - Accounts for fires, floods, seasonality, climate

Resource abundance and HR: examples in literature



**log scale implies a nonlinear effect*

(Kouba et al. 2017)

Resource abundance and HR: examples in literature

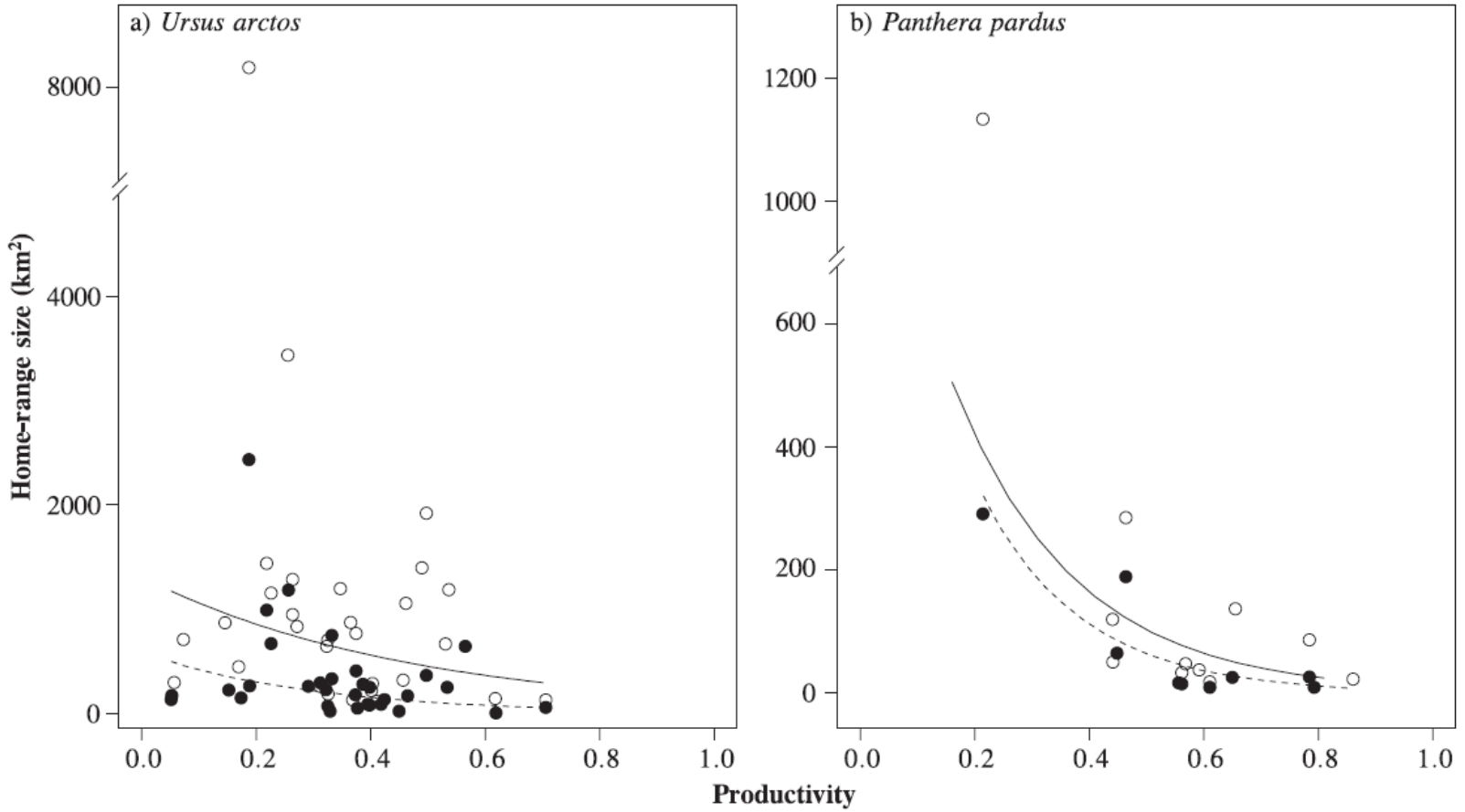


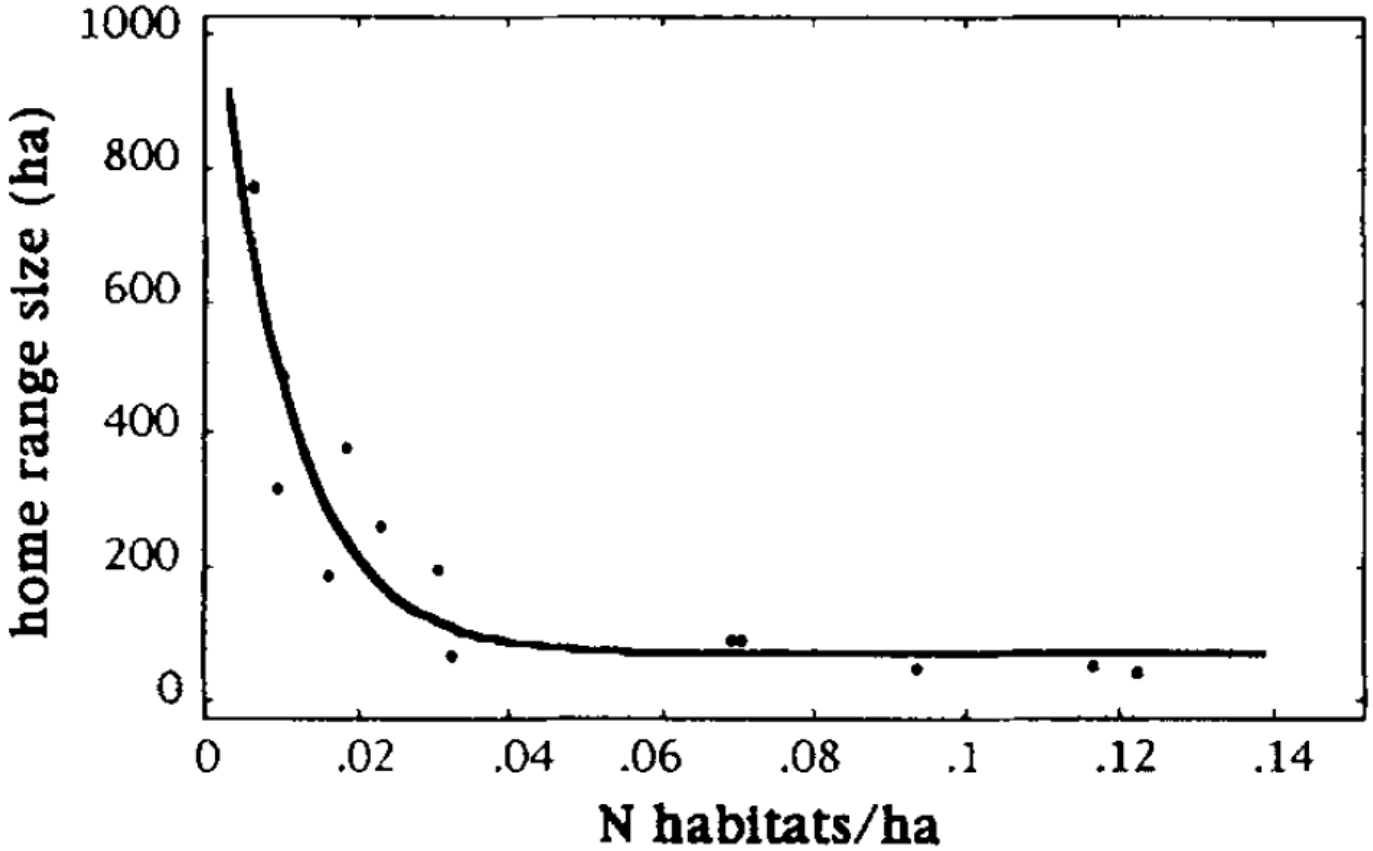
FIGURE 1. The relationship between home-range size and productivity for brown bear (a) and leopard (b). Observed values for females (filled circles) and males (open circles) and the predicted relationship from the selected model for females (dashed line) and males (solid line) appear in the same figure. Note that the home-range size is back-transformed from $\log_{10}$ scale to linear scale. Productivity was estimated as the fraction of photosynthetically active radiation absorbed by the vegetation.

(Nilsen et al. 2005)

Brown bear,
Photo by Yathin S Krishnappa

Leopard,
Photo by Sumeet Moghe

Resource abundance and HR: examples in literature



(Lucherini & Lovari 1996)

Red fox, photo by Airwolfhound

Defining environmental variance

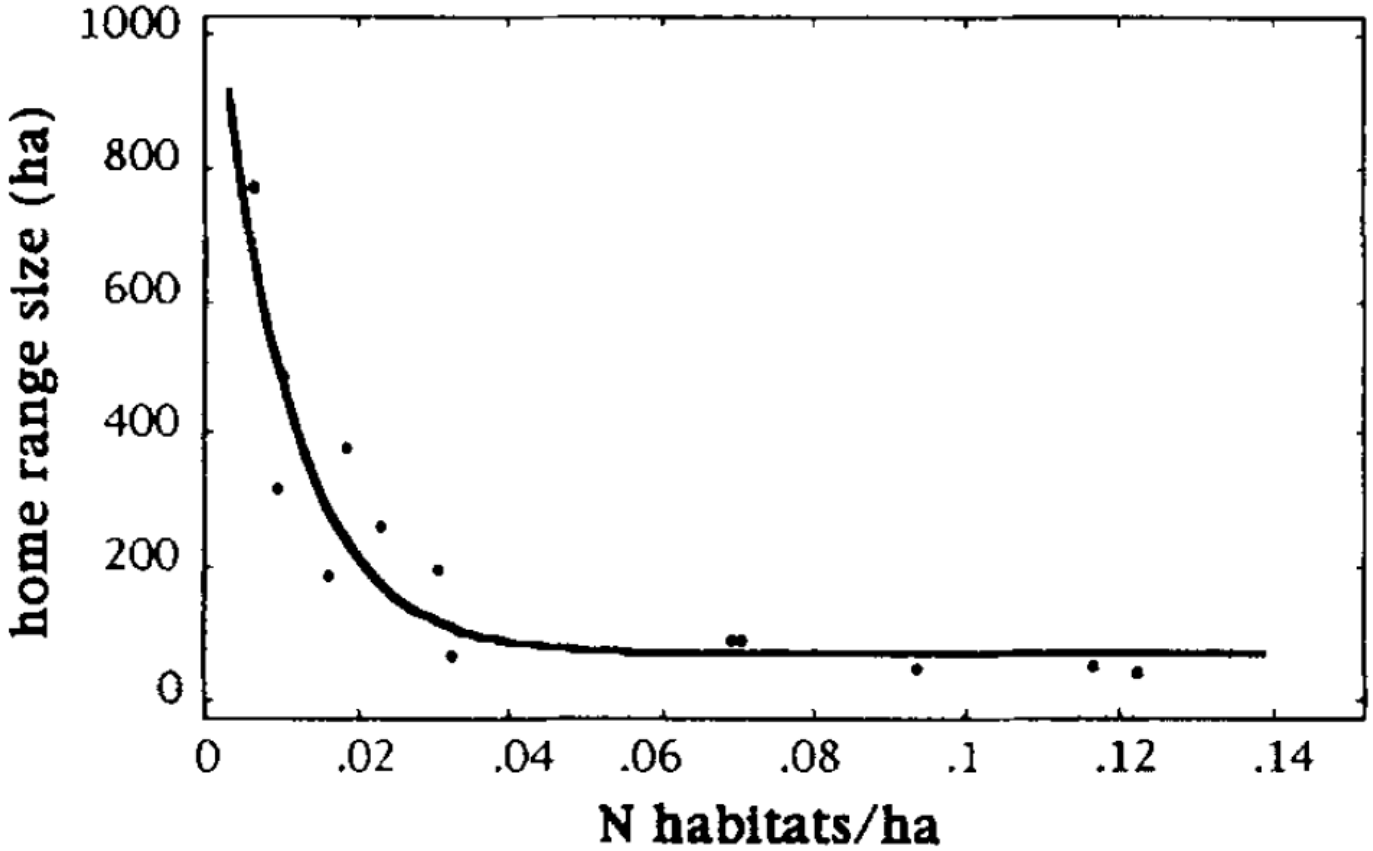
Heterogeneity:

- Different habitats (forest, grassland)
- Seasonal changes (temperature, precipitation, light)
- Altitude, terrain slope

Stochasticity:

- Extreme and rare events (fires, floods)
- Weather, climate change

Variance and HR: examples in literature



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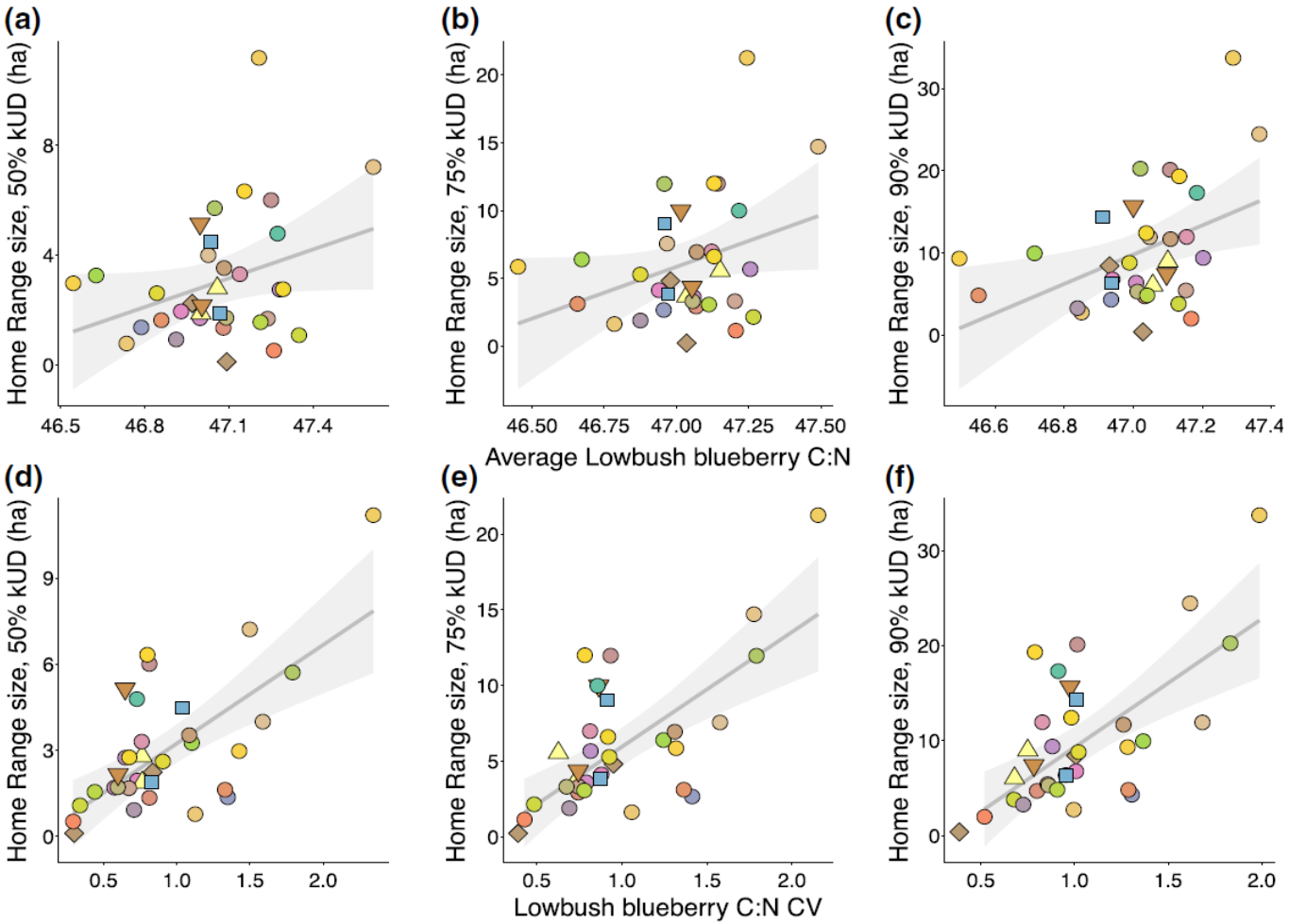
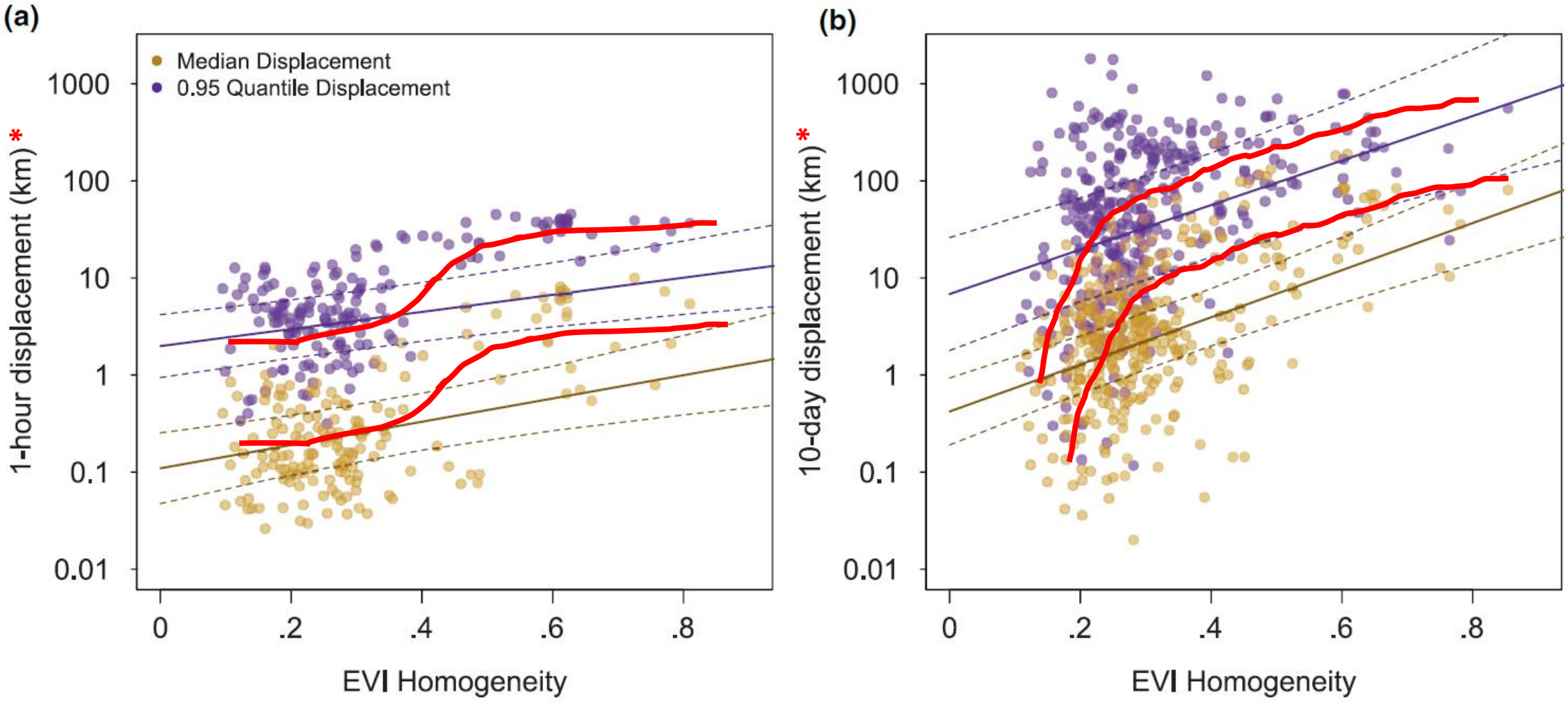
Variance and HR: examples in literature



(Rizzuto et al. 2021)

Showshoe hares,
photos by Wsiegmund (modified)
and D. Gordon E. Robertson

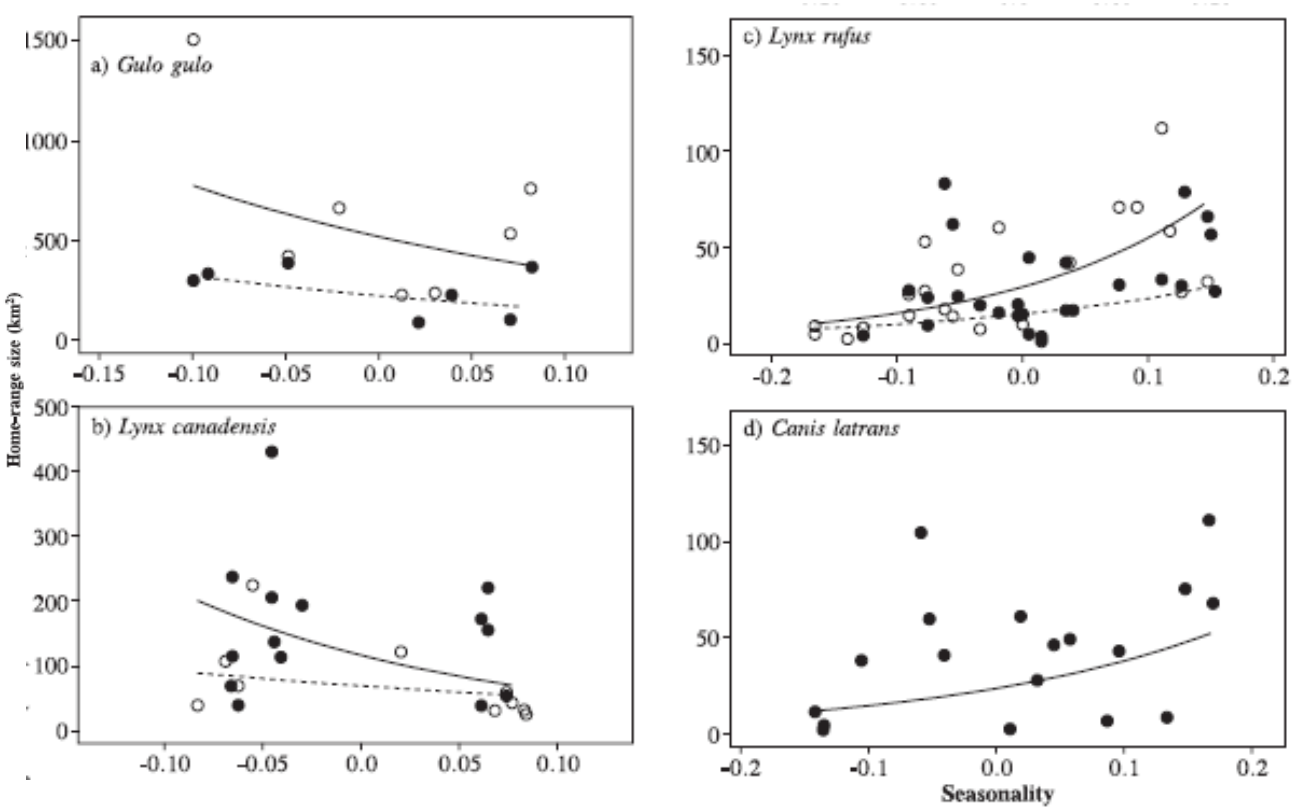
Variance and HR: examples in literature



(Tucker et al. 2018)

**log_10 scale implies a nonlinear effect*

Variance and HR: examples in literature



(Nilsen et al. 2005) (edited)

Wolverine, photo by Zefram

Canadian lynx,
photo by Michael Zahra

Bobcat, photo by Bill W. Ca

Coyote,
photo by Yathin S. Krishnappa

Variance and HR: examples in literature

Wolf, photo by Daniel Mott

Fisher, photo by Douglas H. Domedion

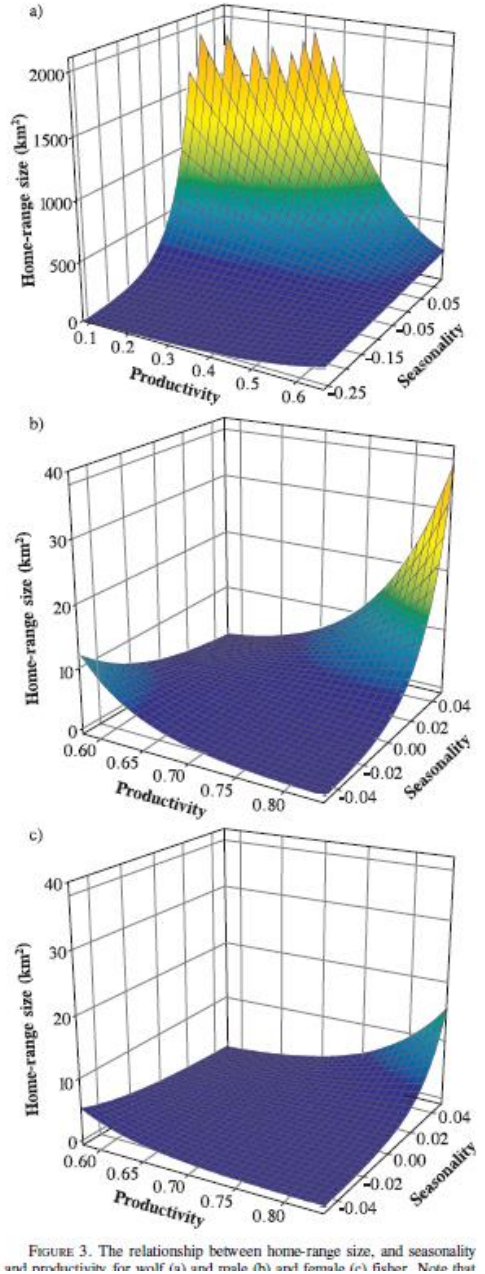


FIGURE 3. The relationship between home-range size, and seasonality and productivity, for wolf (a) and male (b) and female (c) fisher. Note that

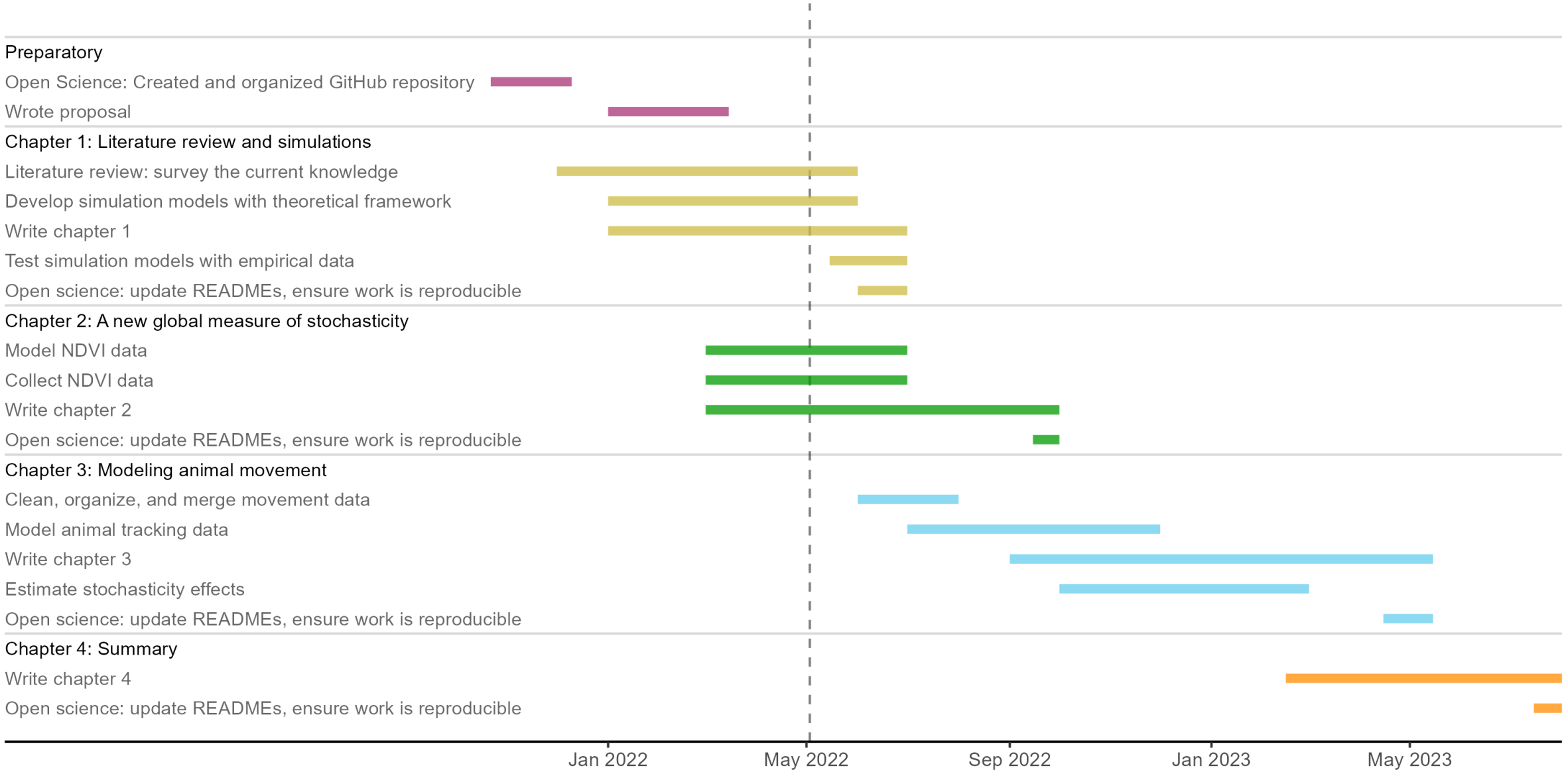
(Nilsen et al. 2005)

The big picture

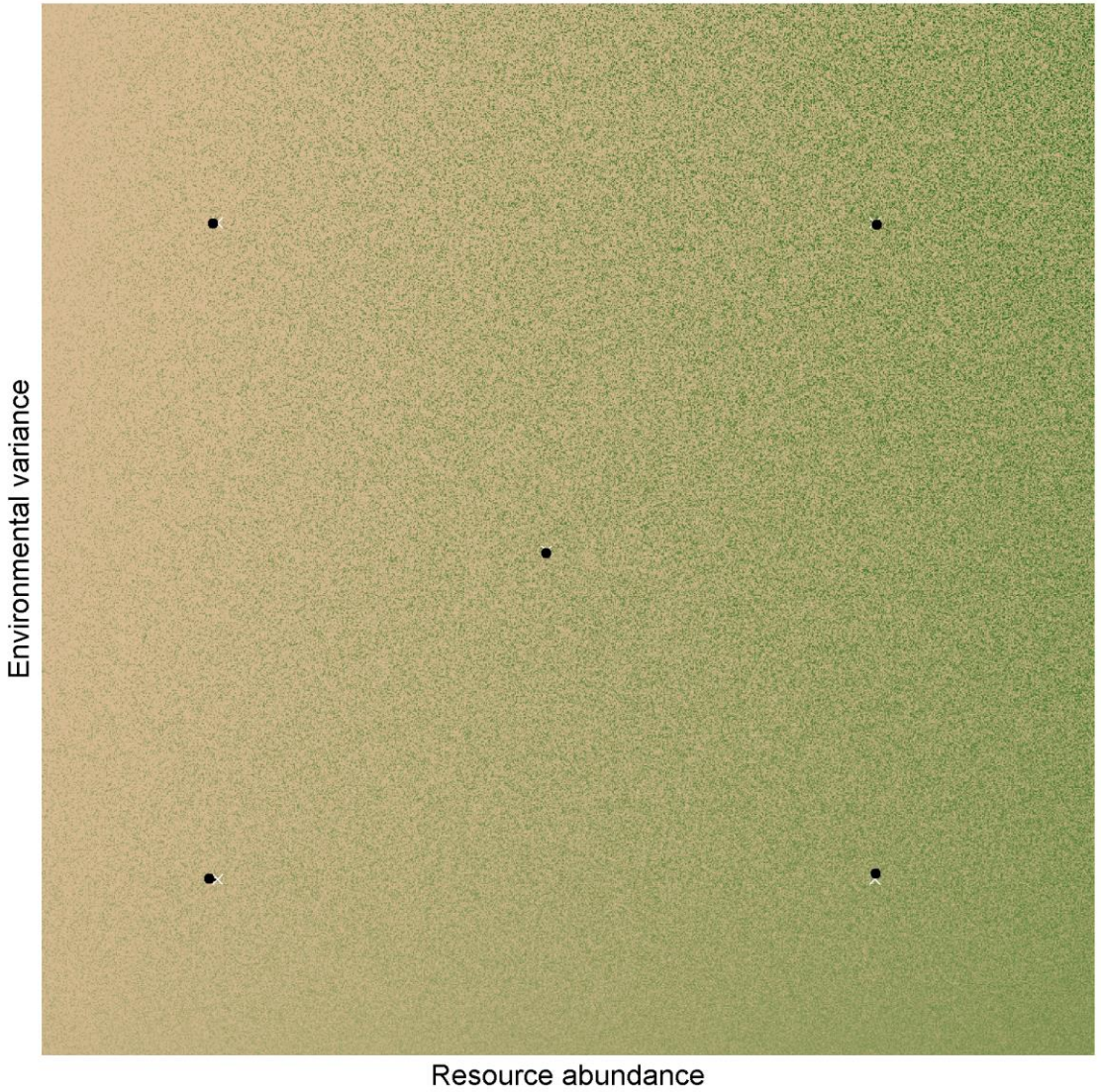
- Some evidence that $\mathbb{E}(U)$ & $\mathbb{V}(U)$ affect HRs
- Effects understudied, especially at large scales

- Estimate the effects of $\mathbb{E}(U)$ & $\mathbb{V}(U)$ using:
  - Scale-invariant simulations
  - Empirical data & modeling

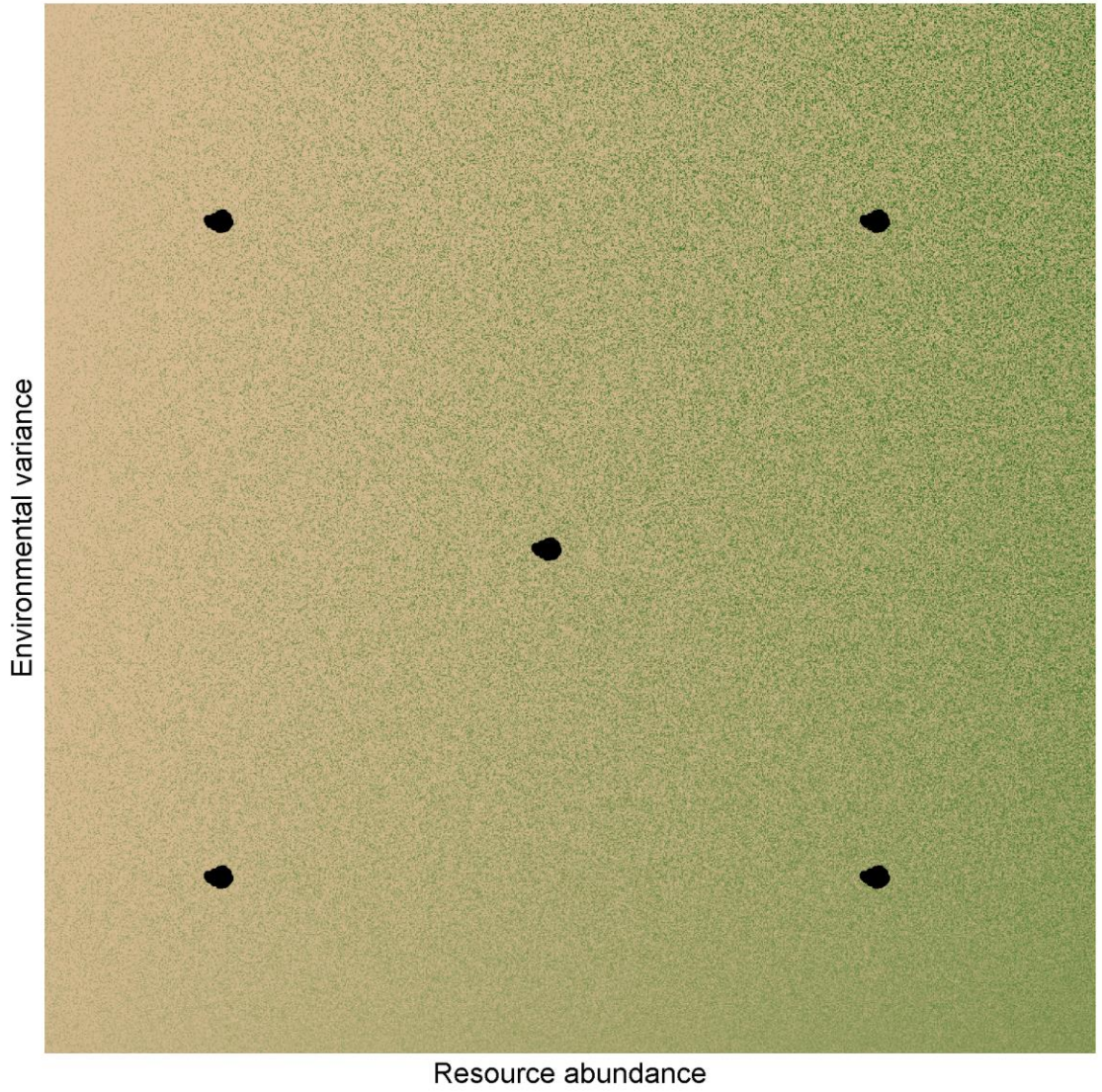
Timeline


Preparatory
Open Science: Created and organized GitHub repository
Wrote proposal
Chapter 1: Literature review and simulations
Literature review: survey the current knowledge
Develop simulation models with theoretical framework
Write chapter 1
Test simulation models with empirical data
Open science: update READMEs, ensure work is reproducible
Chapter 2: A new global measure of stochasticity
Model NDVI data
Collect NDVI data
Write chapter 2
Open science: update READMEs, ensure work is reproducible
Chapter 3: Modeling animal movement
Clean, organize, and merge movement data
Model animal tracking data
Write chapter 3
Estimate stochasticity effects
Open science: update READMEs, ensure work is reproducible
Chapter 4: Summary
Write chapter 4
Open science: update READMEs, ensure work is reproducible
Jan 2022
May 2022
Sep 2022
Jan 2023
May 2023

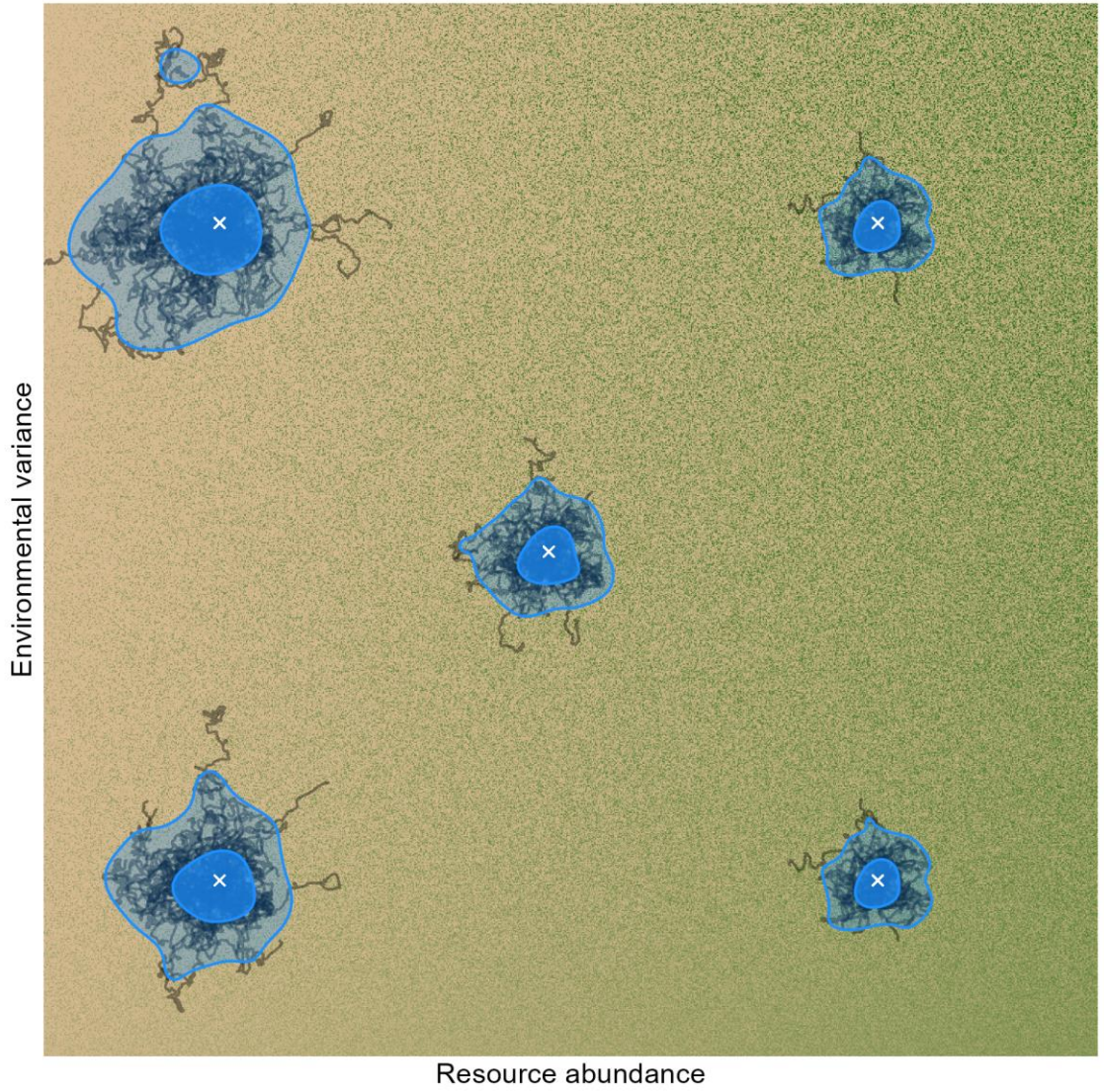
Abundance, variance and HR: simulating movement



Abundance, variance and HR: simulating movement

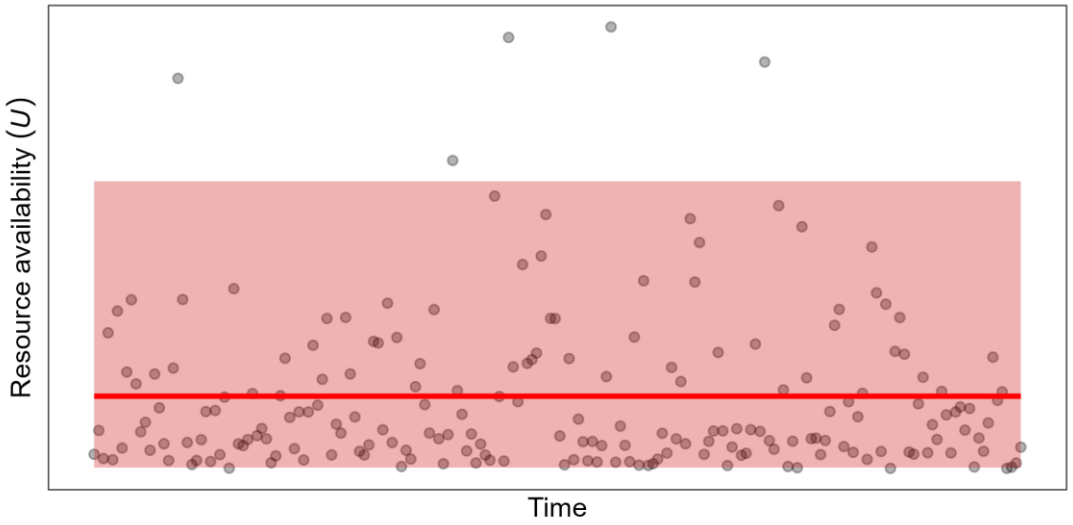


Abundance, variance and HR: simulating movement

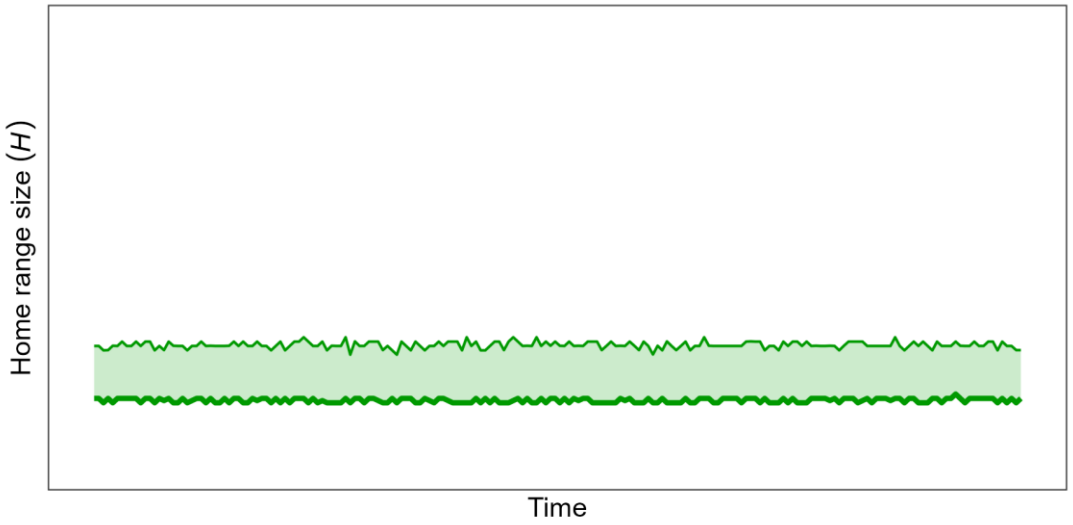


Stationary environments --> constant HR

- Constant mean
- Constant variance

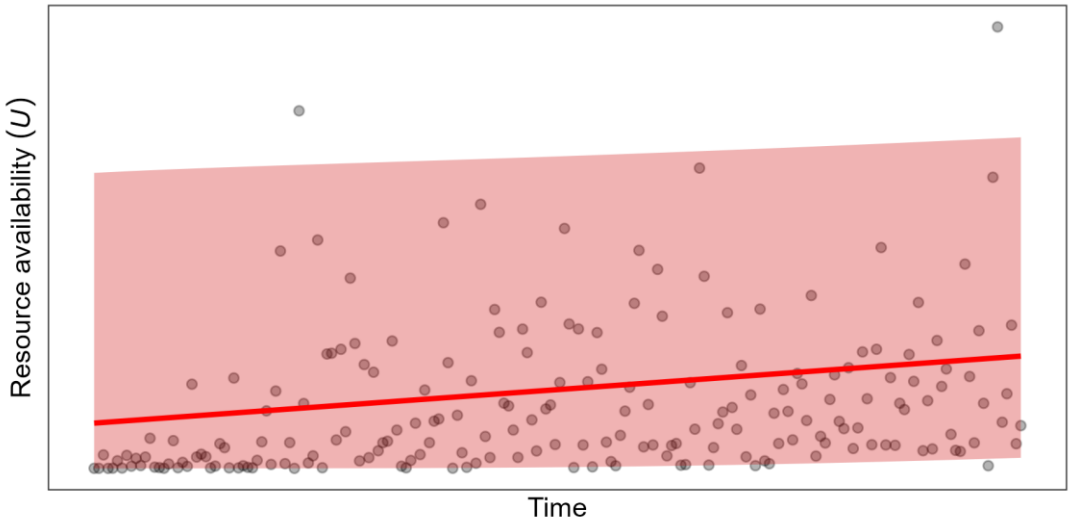


- HR remains constant over time

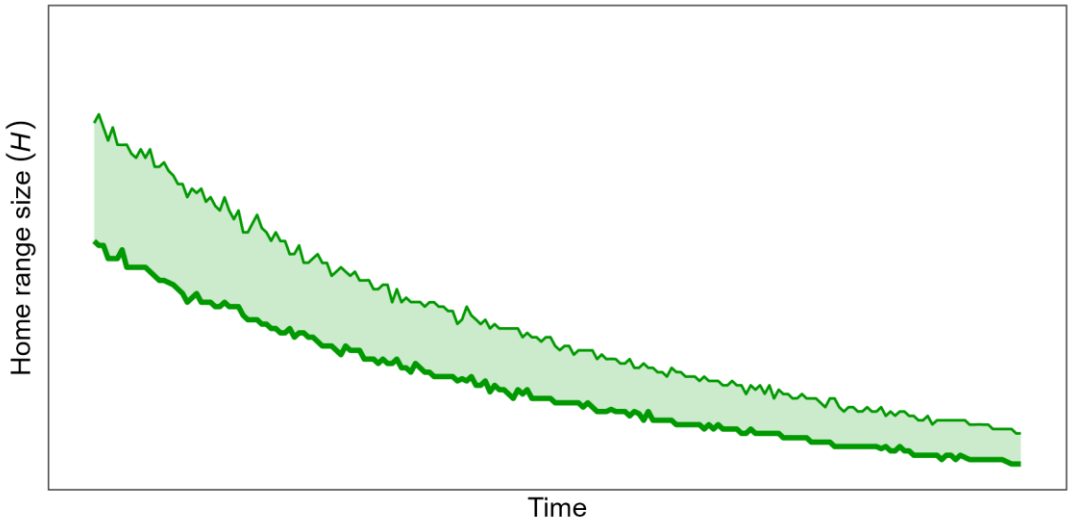


Changing mean --> HR changes rapidly

- Linearly increasing mean
- Constant variance

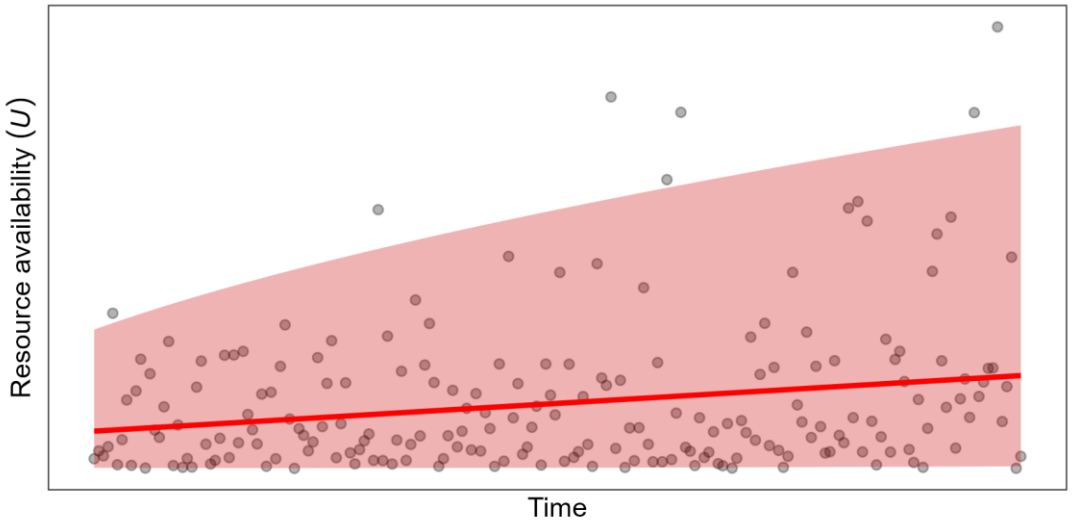


- HR ∝ 1/availability
- 95% HR decreases faster

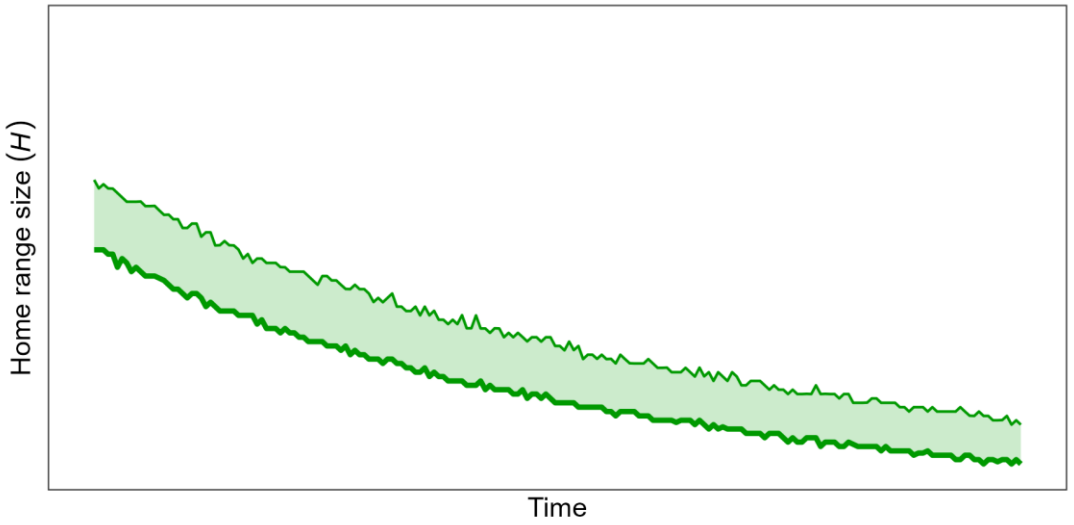


Changing mean and variance --> HR can change slowly

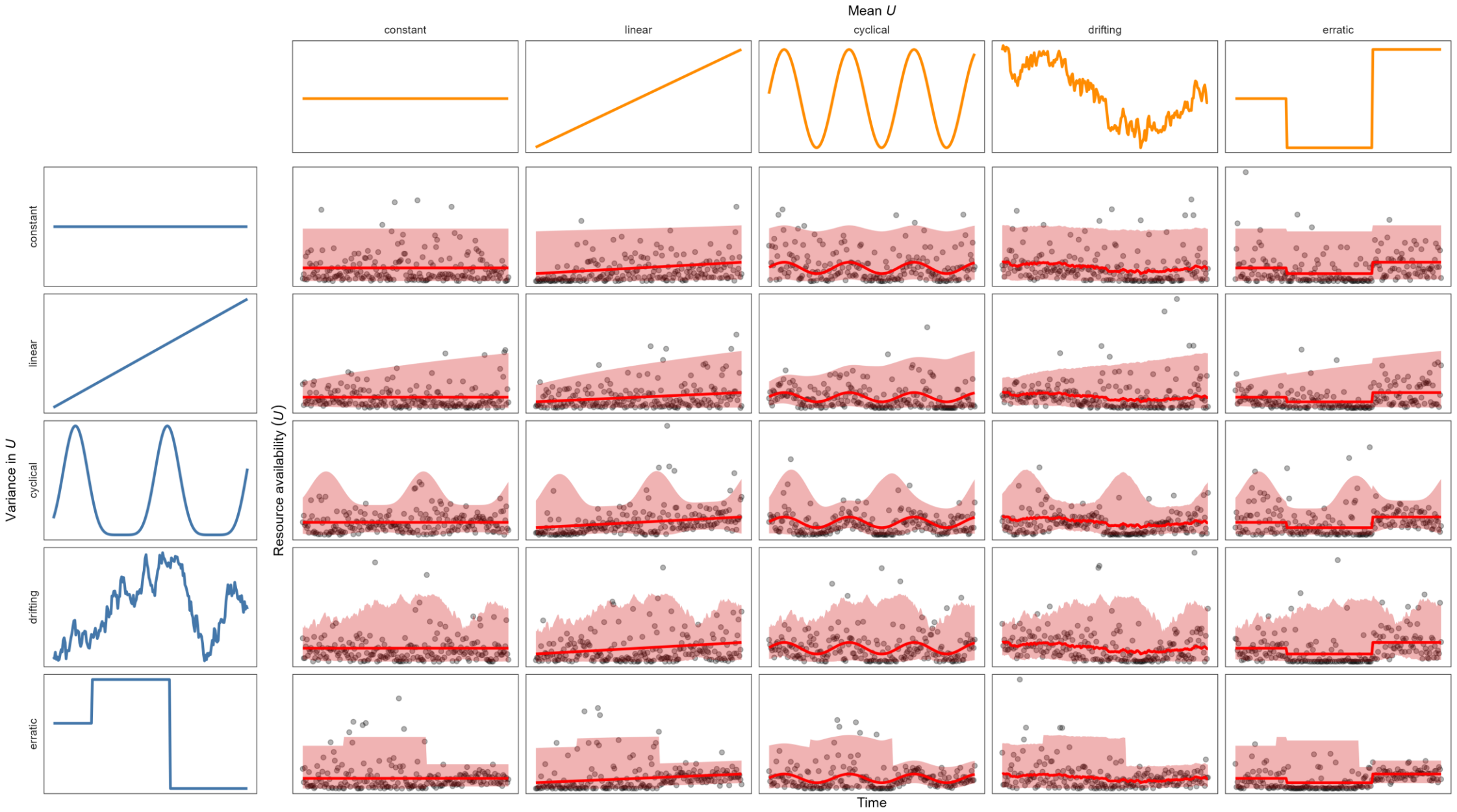
- Linearly increasing mean
- Linearly increasing variance



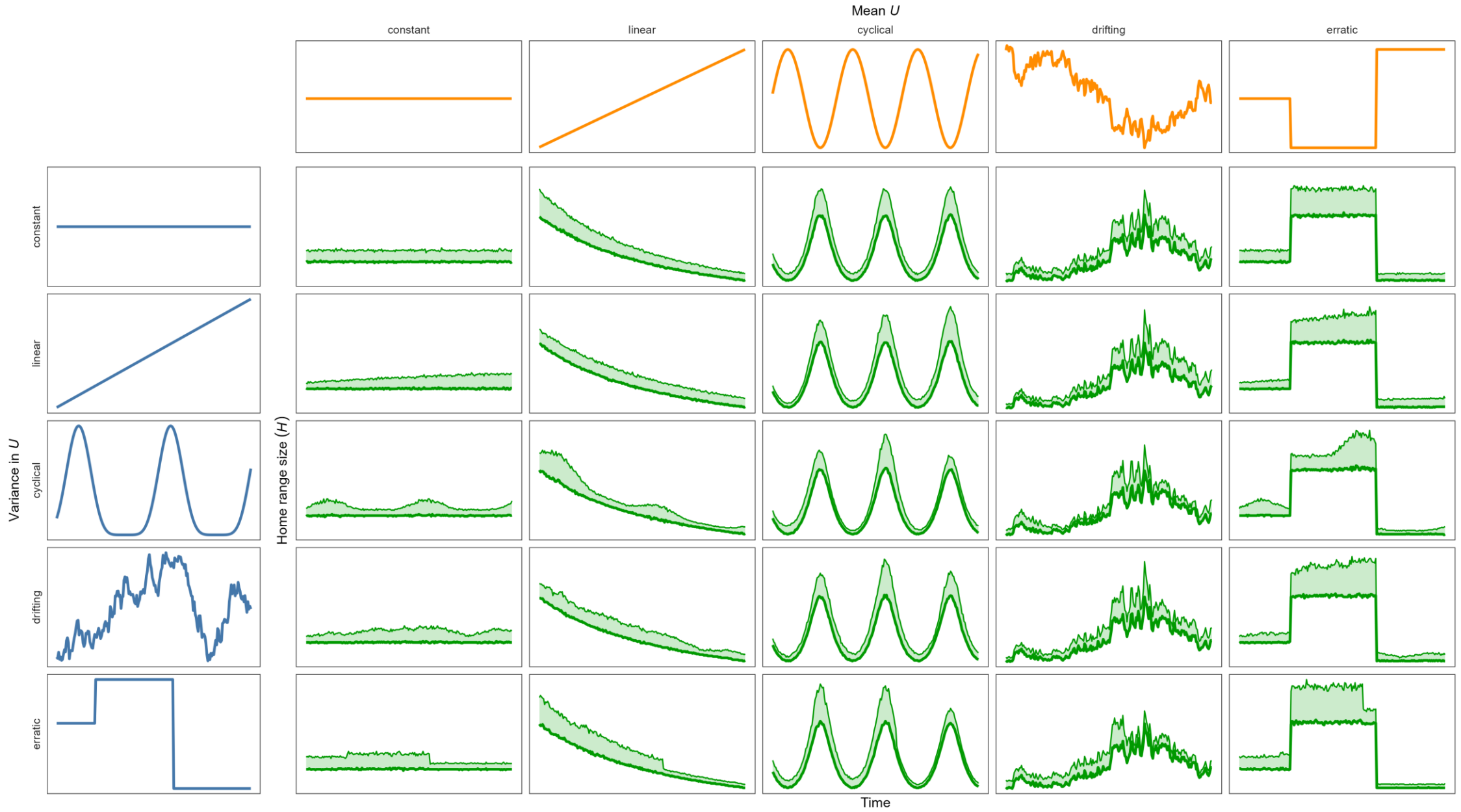
- HR ∝ 1/availability
- 95% HR and 50% HR decrease at a similar speed



Relationships can be complicated…



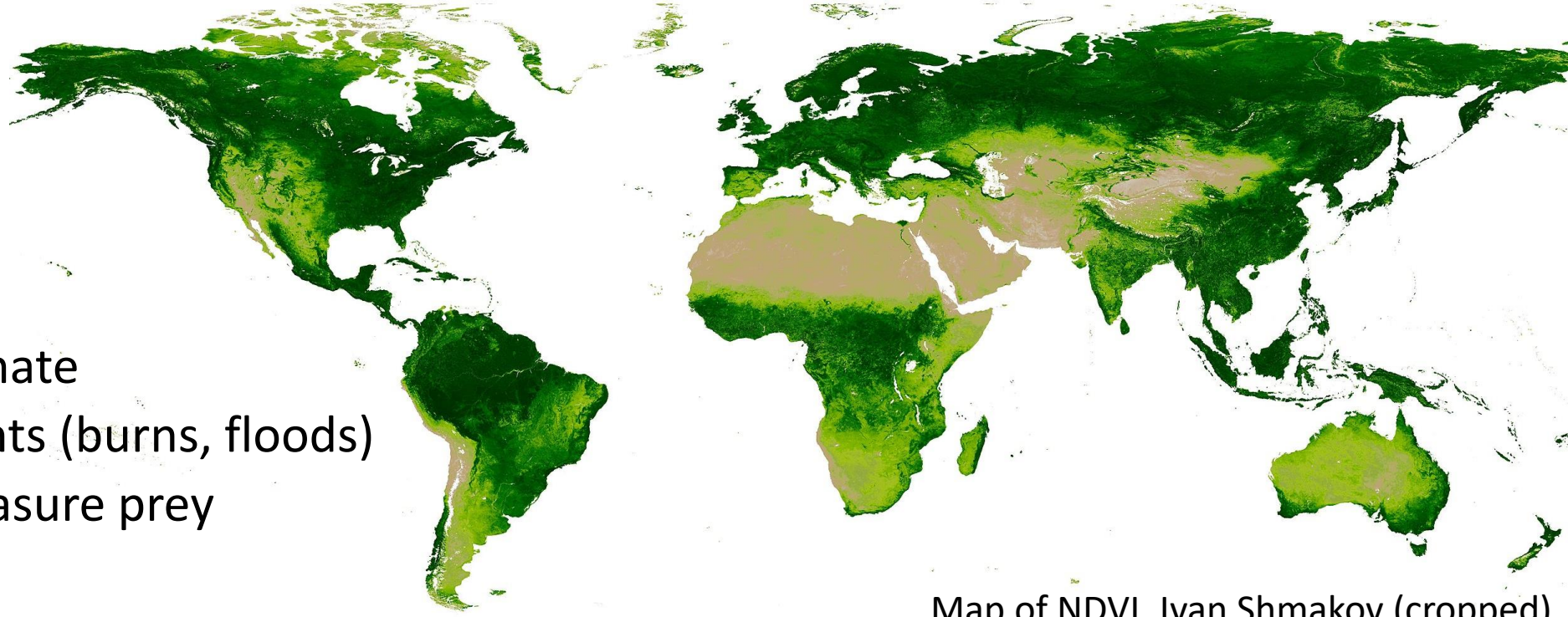
…but simulations can help!



Modeling environmental variance

NDVI:

- Productivity
- Seasonality
- Weather, climate
- Extreme events (burns, floods)
- Does not measure prey

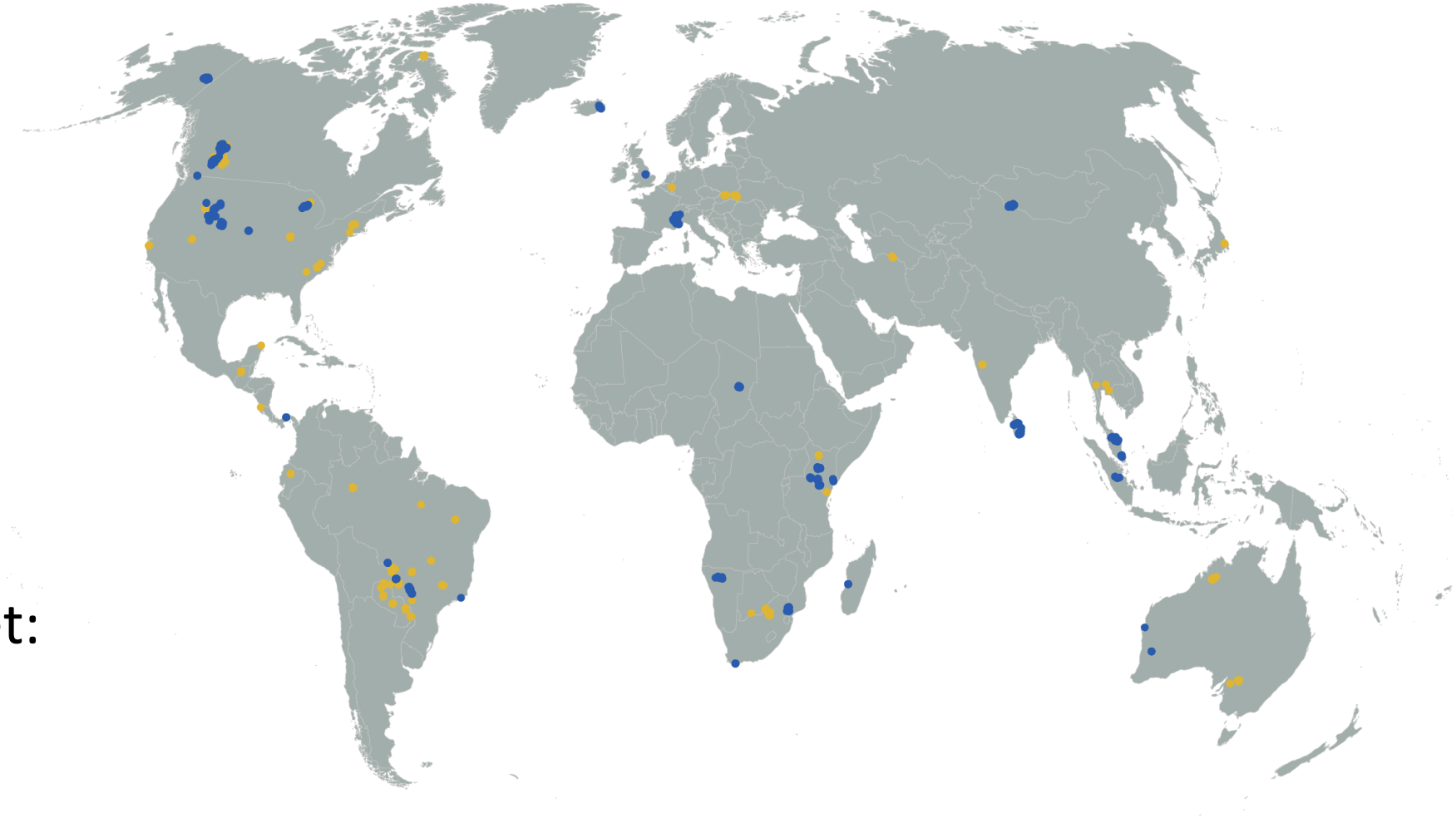


Map of NDVI, Ivan Shmakov (cropped)

Location-scale model:

- Model mean and variance together
- `brms` R package
- $\text{Beta}(\mu, \phi)$ distribution

Modeling it all



- Movebank dataset:
  - ~ 2000 animals
  - ~ 80 species
- Raster of environmental variance
- Continuous time movement models (`ctmm` R package)
- Hierarchical modeling for common trends (`mgcv` R package)

Funder acknowledgements

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Summary

- Can measure HR as a **catch-all variable** for animal's needs
- Effects of $\mathbb{E}(U)$ & $\mathbb{V}(U)$ on HRs are understudied
- Estimate the effects using:
  - Scale-invariant simulations
  - Tracking data --> CTMMs --> hierarchical modeling

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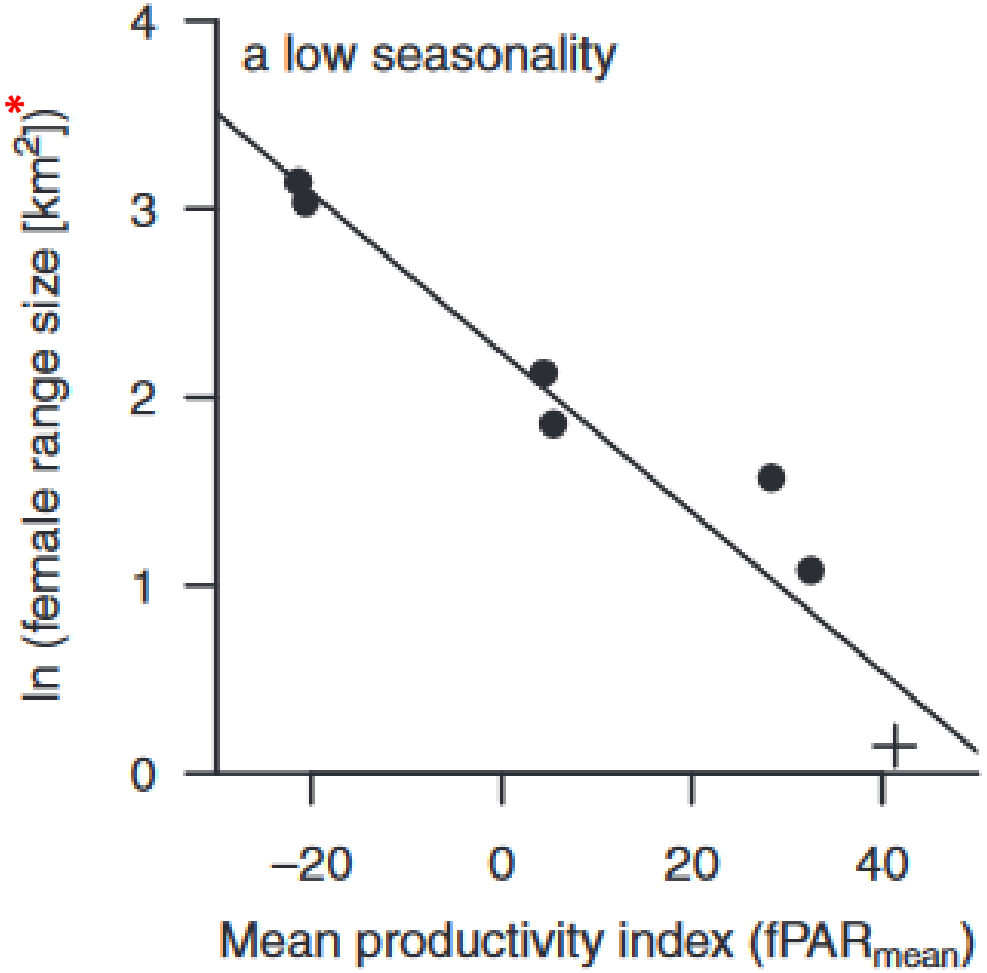
Additional slides

Resource abundance and HR: examples in literature



Outdoor or feral cat, photo by Brocken Inaglory

**log scale implies a nonlinear effect*

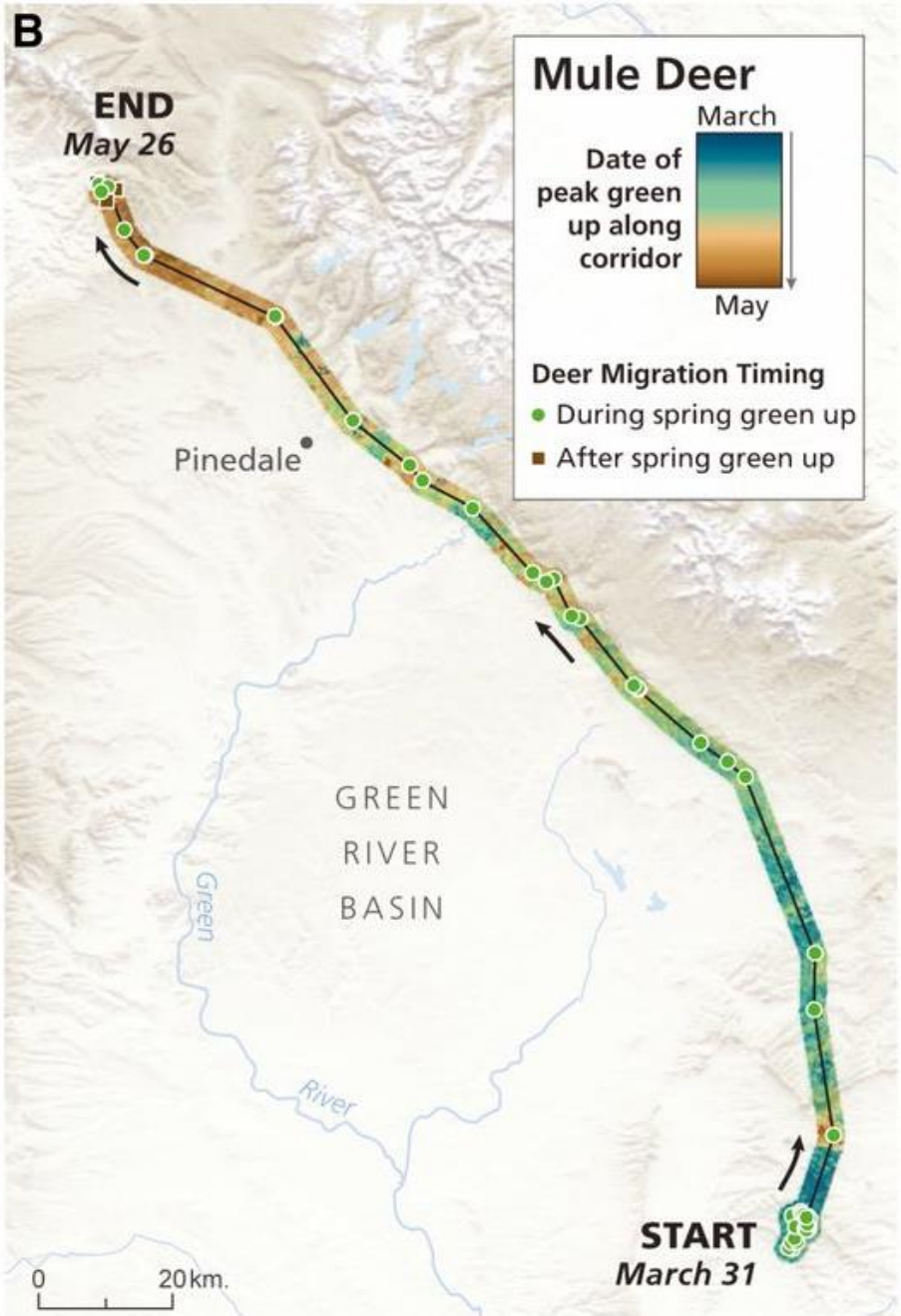
(Bengsen et al. 2015)

Variance and HR: examples

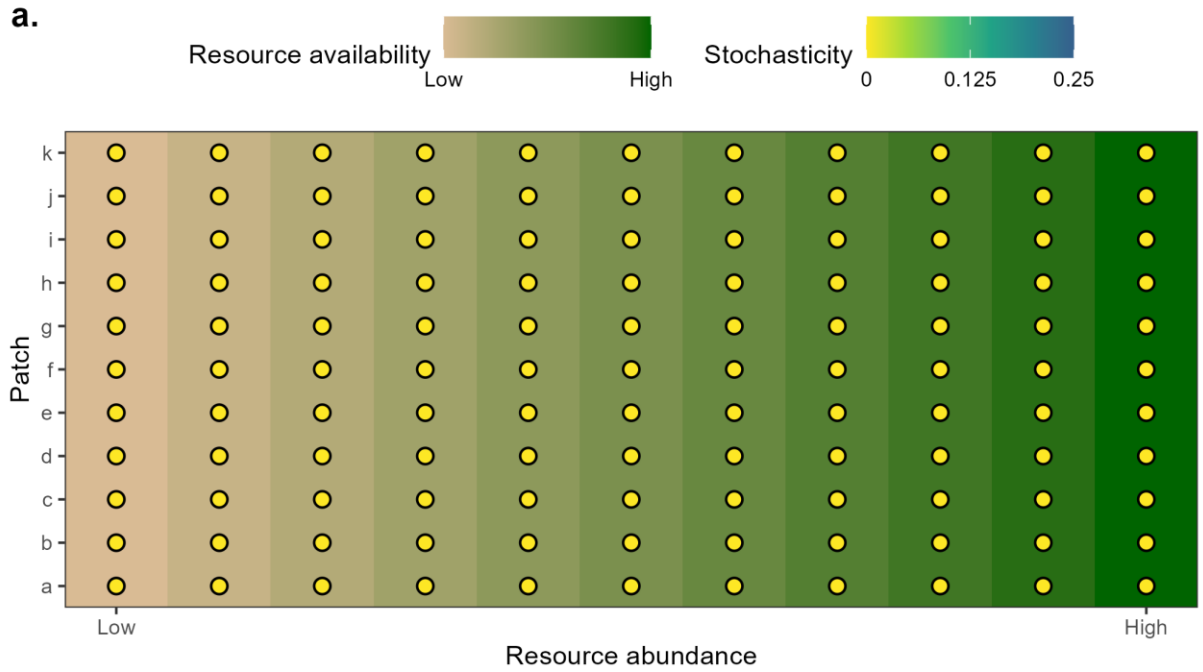
- A deer surfs the green wave

Foraging deer, https://www.havahart.com/media/Articles/Havahart/Protecting-Plants-from-Deer.jpg

(Geremia et al. 2019)



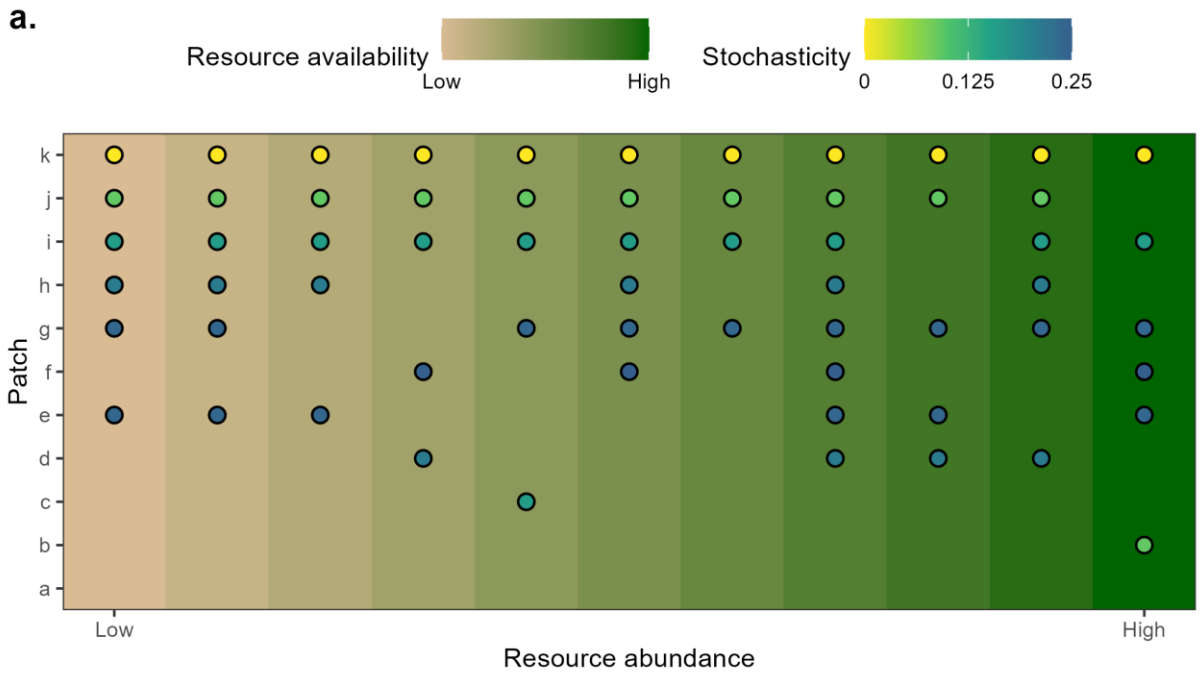
Stable environments --> stable needs



In predictable environments:

- P(success) = 1 (no failures)
- Availability = Abundance
- Prefer high-abundance areas
- $U = R \times S = R \times 1 = R$
- $\mathbb{E}(U) = R \times \mathbb{E}(S) = R \times 1 = R$

Variable environments --> variable needs



In unpredictable environments:

- P(success) ≠ 1 (failures happen)
- Availability ≤ Abundance
- Prefer high-availability areas
- $U = R \times S \leq R$
- $\mathbb{E}(U) = \mathbb{E}(R \times S) \leq \mathbb{E}(R)$

Simulating movement