How do resource abundance and stochasticity affect animal movement?

Quantitative Ecology Lab
UBC Okanagan

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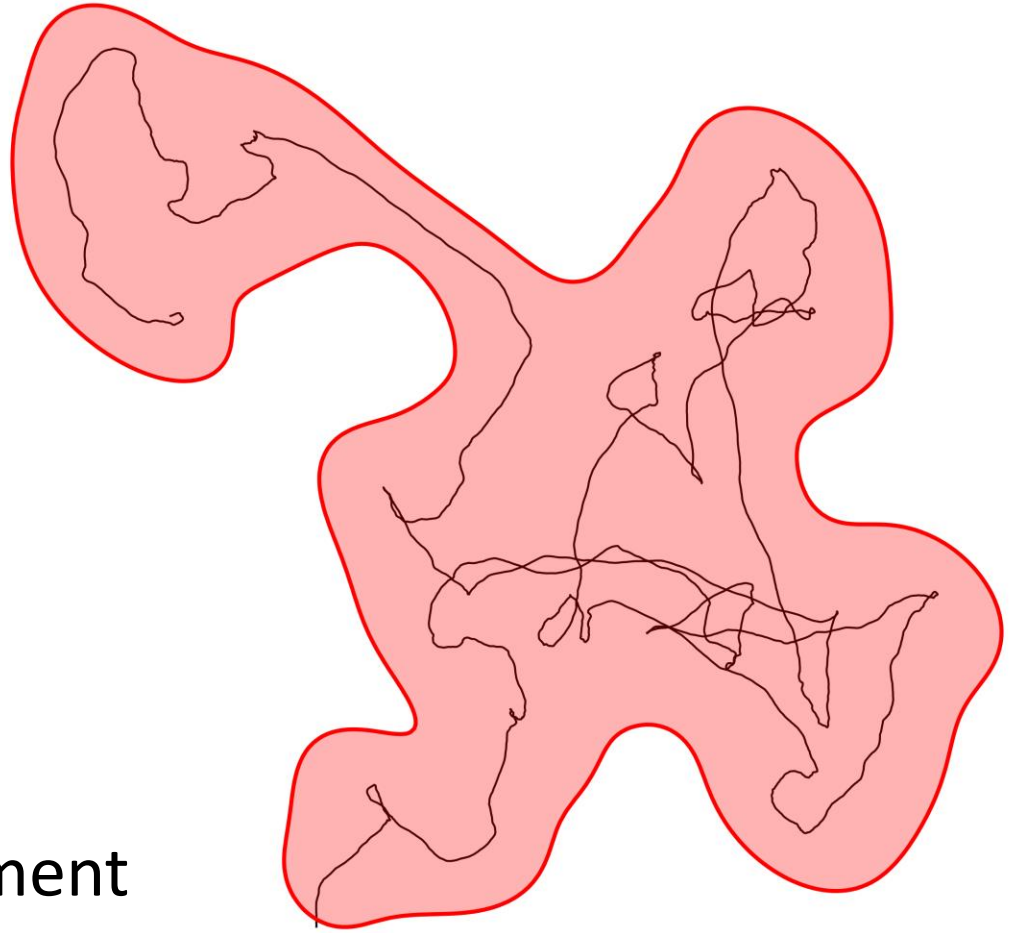
Why do animals move?

- Searching for food/nutrients
- Searching for water
- Searching for new den/nest
- Searching for mate/group
- Escaping predators/competitors
- Defending resources/territory

Can measure HR instead of individual needs

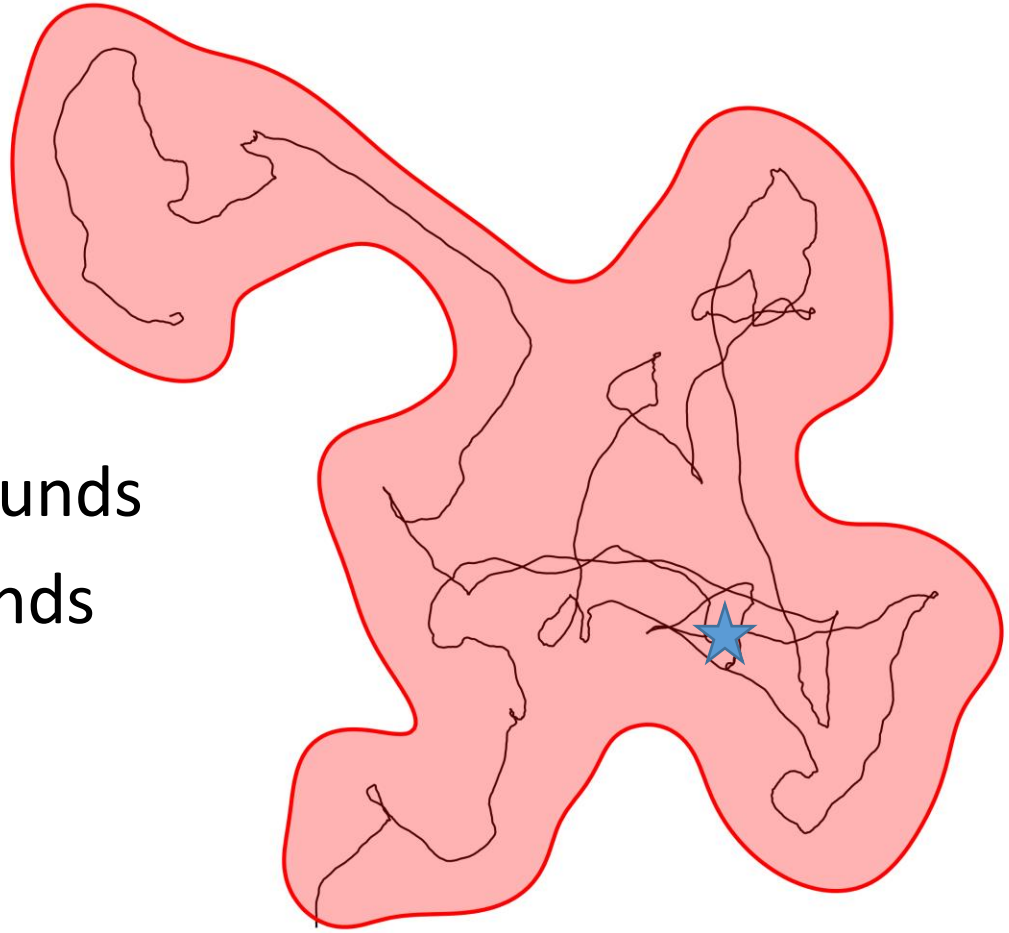
What is a home range?

- Area required for essential needs
- Animals must be range-resident
- HR must have a stable centroid
- Not applicable to:
  - Nomadic animals
  - Migrating animals
- May change over time
- Does not include exploratory movement



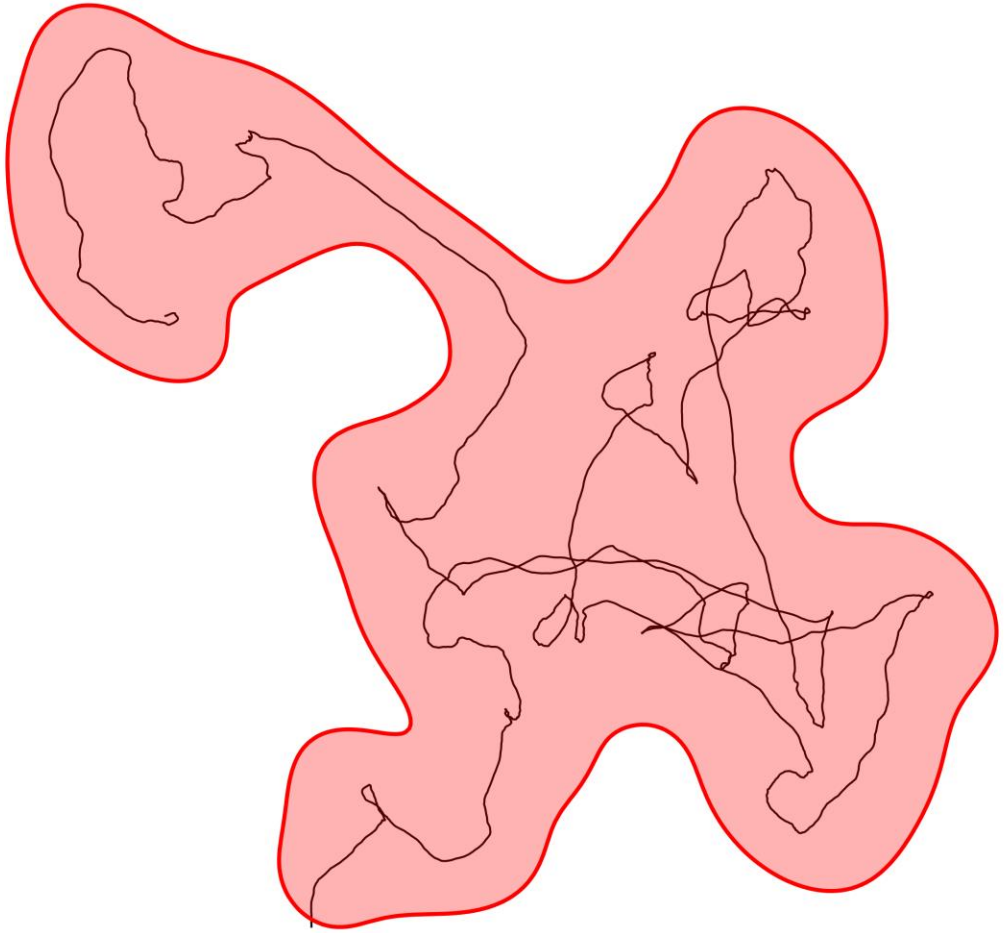
HR modeling requires a stable centroid

- An eagle returning to its nest
- A bear returning to its den
- A bee returning to its hive
- The center of a coyote's hunting grounds
- The center of a deer's foraging grounds



What might affect HR size?

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



Resource abundance and HR: examples

- An eagle nests near areas with high prey density

Bald eagle, photo by KenCanning

Resource abundance and HR: examples

- A bear stays near a river where salmon spawn

Bears eating salmon,
https://hakaimagazine.com/wp-content/uploads/header-inland-salmon.jpg

Resource abundance and HR: examples

- A bee focuses on wildflower patches and ignores crops

Bee pollinating a wild flower,
https://www.goodnet.org/photos/620x0/29855_hd.jpg

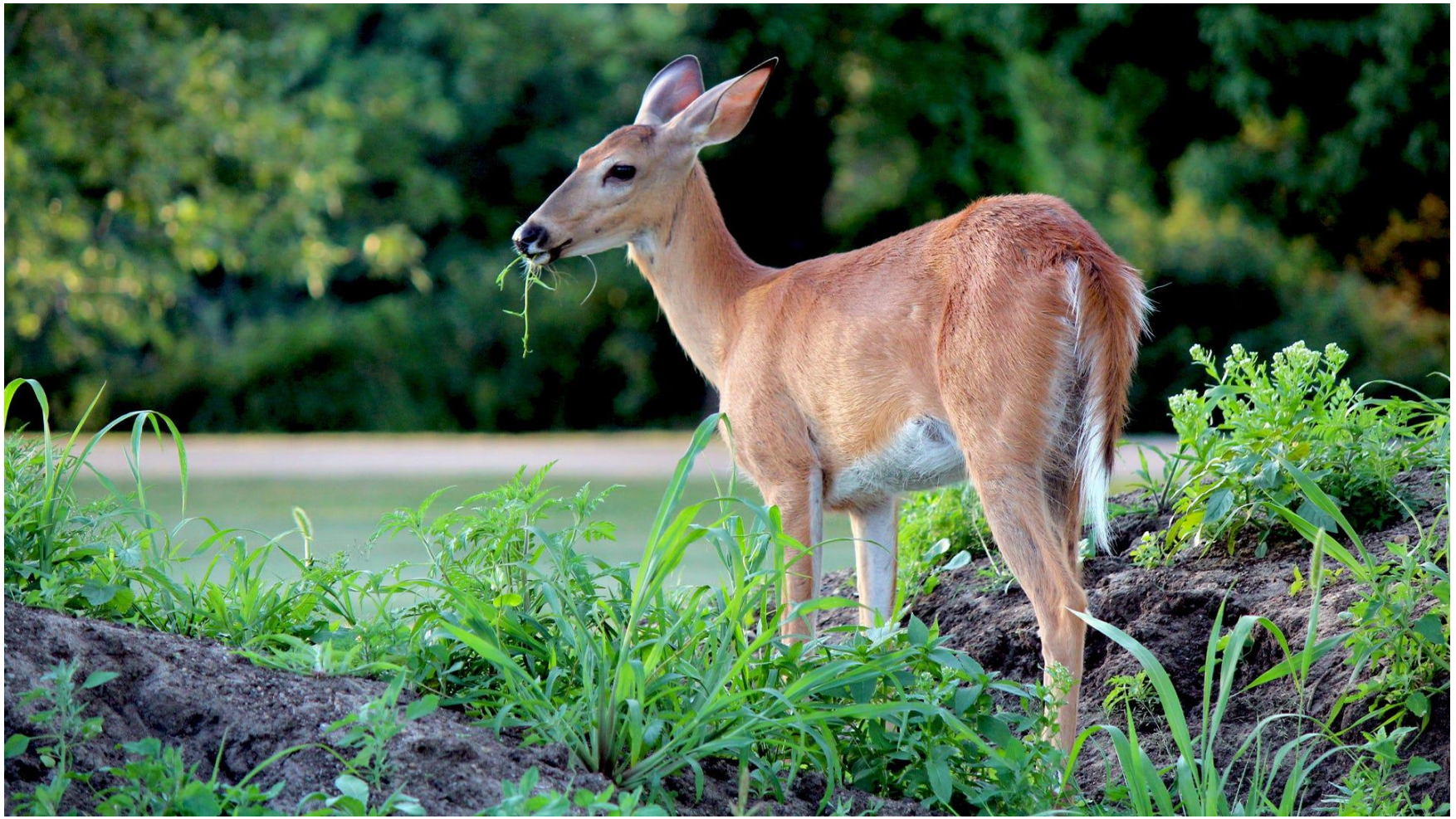
Resource abundance and HR: examples

- A coyote takes advantage of pet food

Coyote in an urban environment,
https://www.economist.com/img/b/1280/720/90/sites/default/files/20200118_USP002.jpg

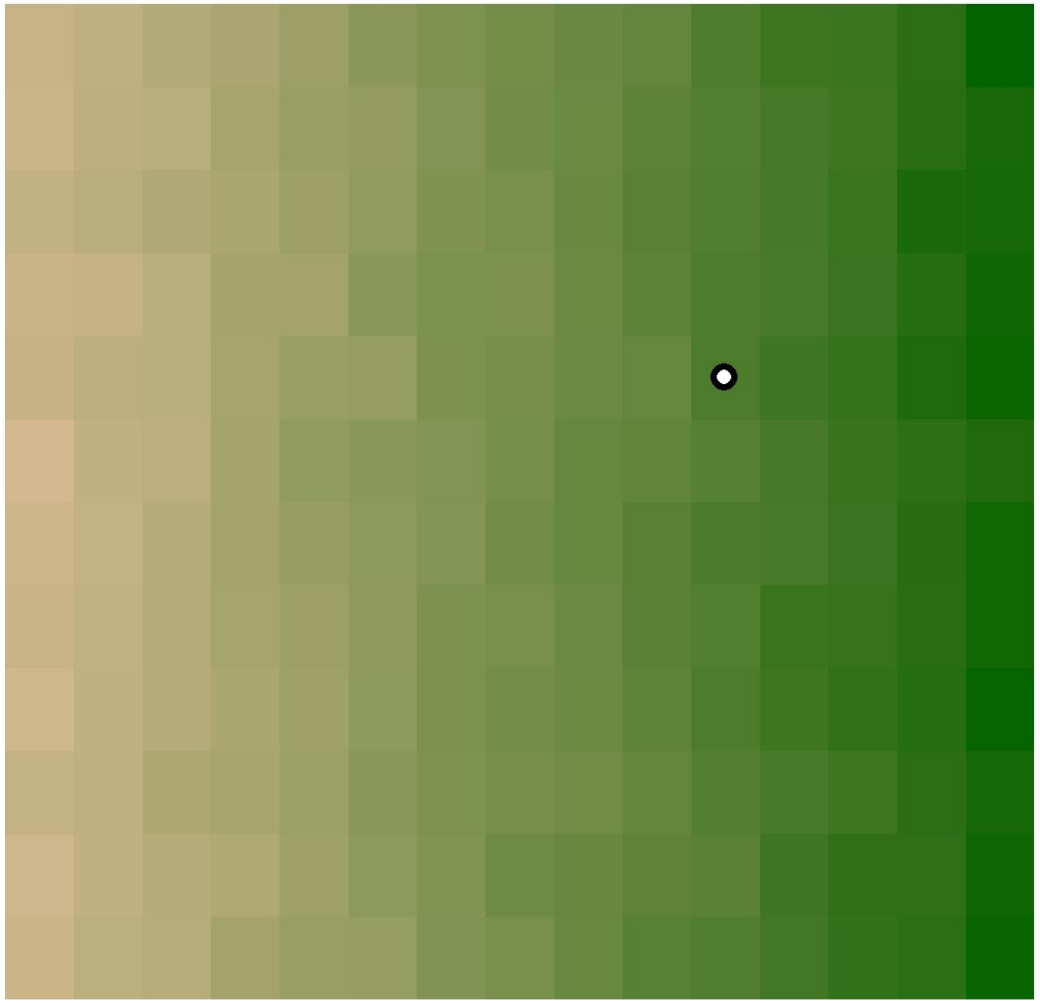
Resource abundance and HR: examples

- A deer only stops at vegetation-rich patches



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

Resource abundance and HR: simulating movement



Resource abundance

Resource abundance and HR: examples in literature

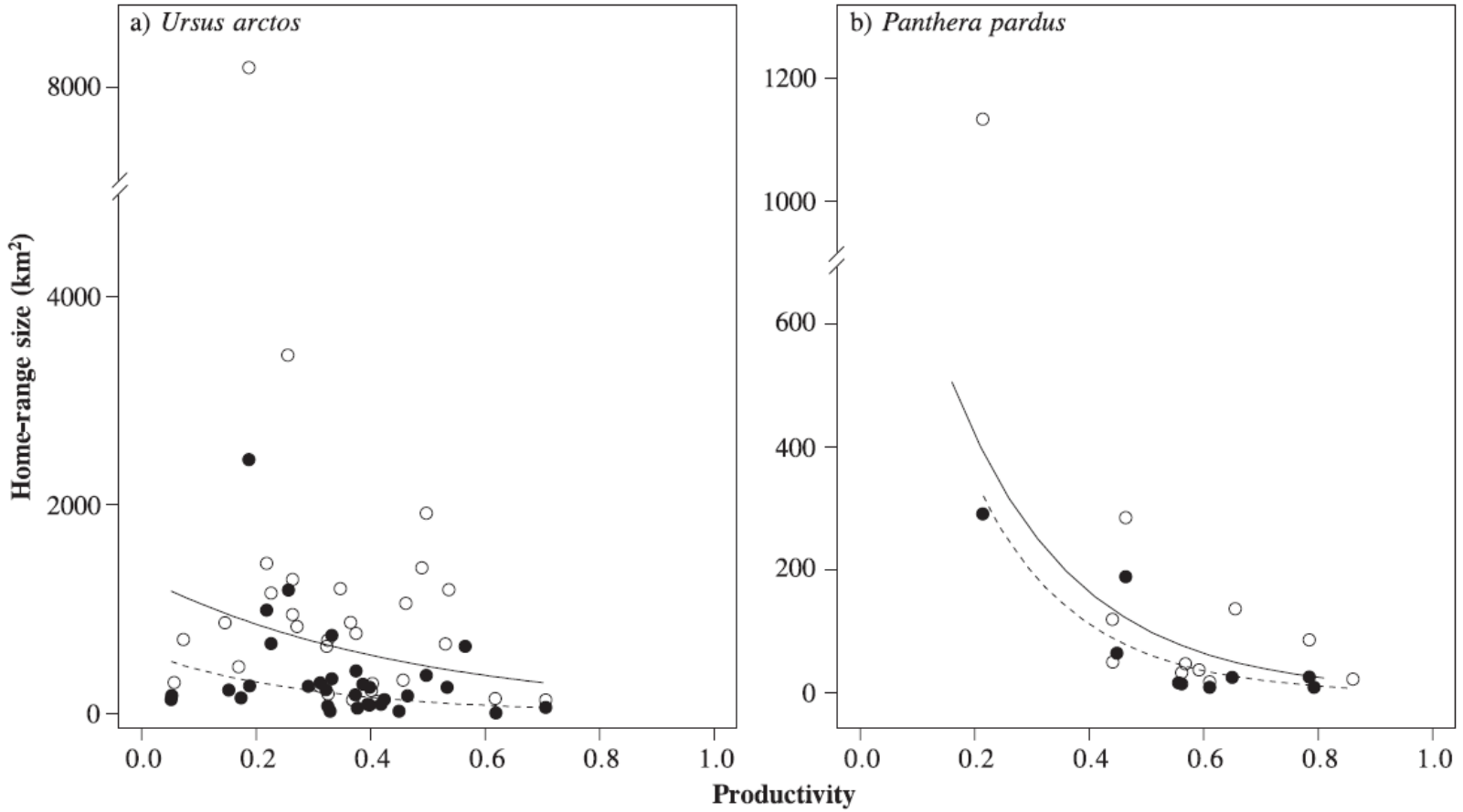


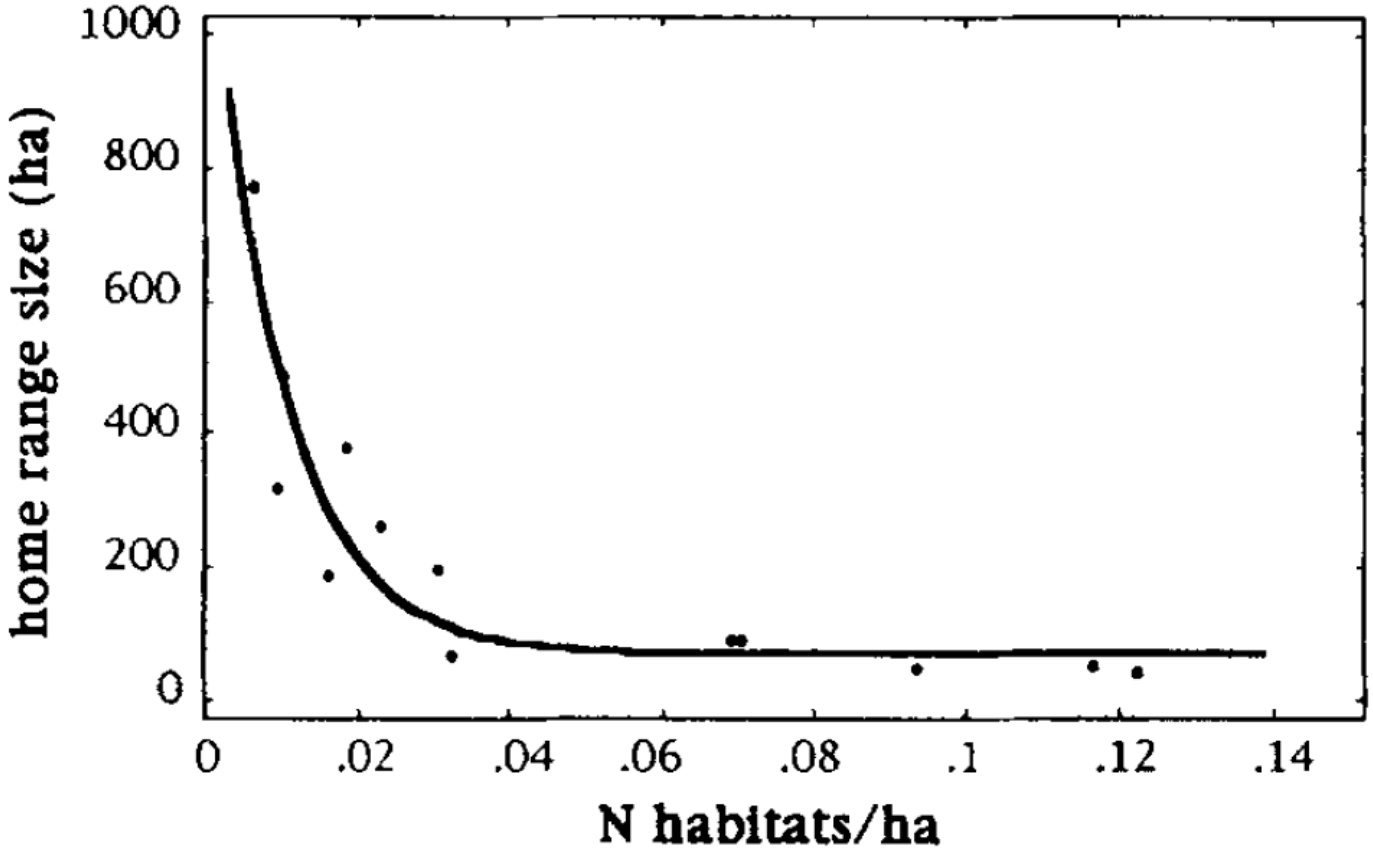
FIGURE 1. The relationship between home-range size and productivity for brown bear (a) and leopard (b). Observed values for females (filled circles) and males (open circles) and the predicted relationship from the selected model for females (dashed line) and males (solid line) appear in the same figure. 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

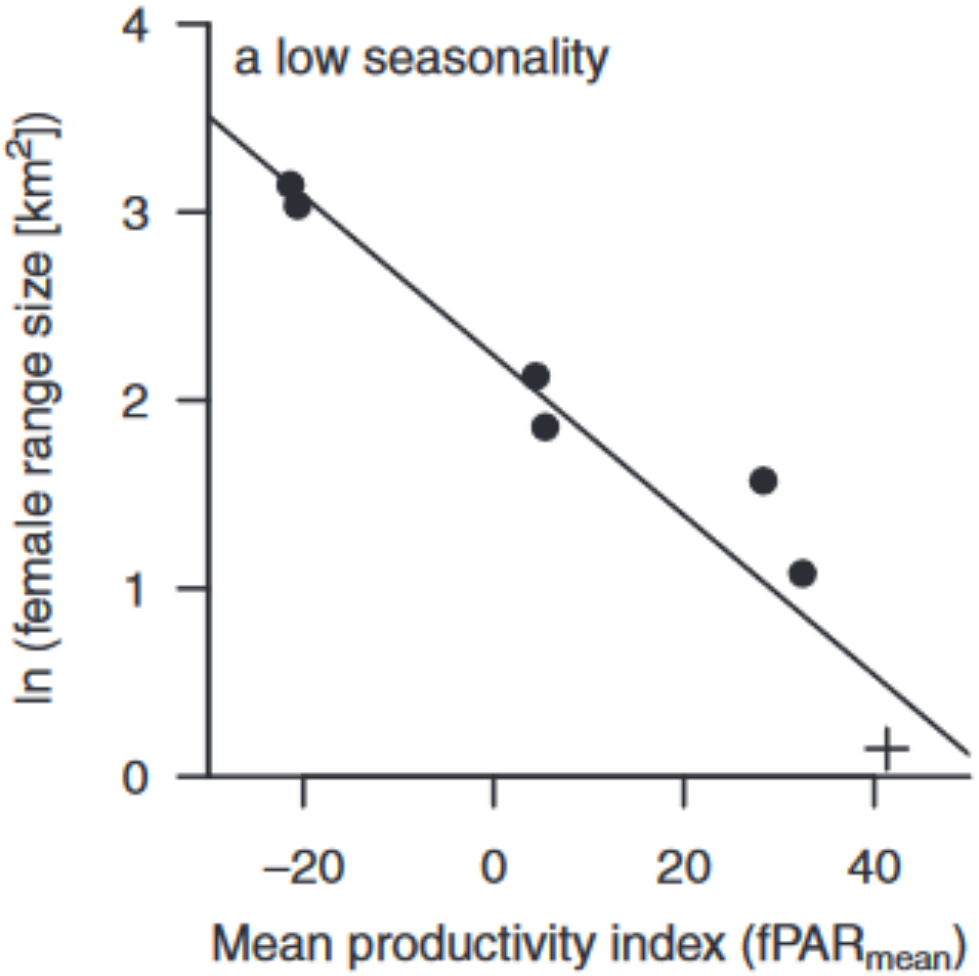
Resource abundance and HR: examples in literature



(Lucherini & Lovari 1996)

Red fox, photo by Airwolfhound

Resource abundance and HR: examples in literature



Outdoor or feral cat, photo by Brocken Inaglory

(Bengsen et al. 2015)

Environmental variance is also important

Heterogeneity:

- Different habitats (forest, grassland, lake…)
- Seasonal changes (temperature, precipitation, light)

Stochasticity:

- Extreme and rare events (fire, flood)
- Climate change

Variance and HR: examples

- A pair of eagles nests near forest edges to be near the open grassland

Nesting bald eagles with chicks,
https://www.birdsandblooms.com/wp-content/uploads/2017/05/eaglenest_tonya-sharp-e1638205400987.jpg

Variance and HR: examples

- A bear hibernates in winter and visits the river when salmon spawn

Hibernating black bear,
https://bear.org/wp-content/uploads/2008/10/bear_curled_up_in_den.jpg

Variance and HR: examples

- A bee only leaves the nest when it’s dry, warm, and not windy

Bees on honeycomb,
https://www.zooportraits.com/wp-content/uploads/2017/03/bees.jpg

Variance and HR: examples

- A coyote takes advantage of the feeding schedule of pets

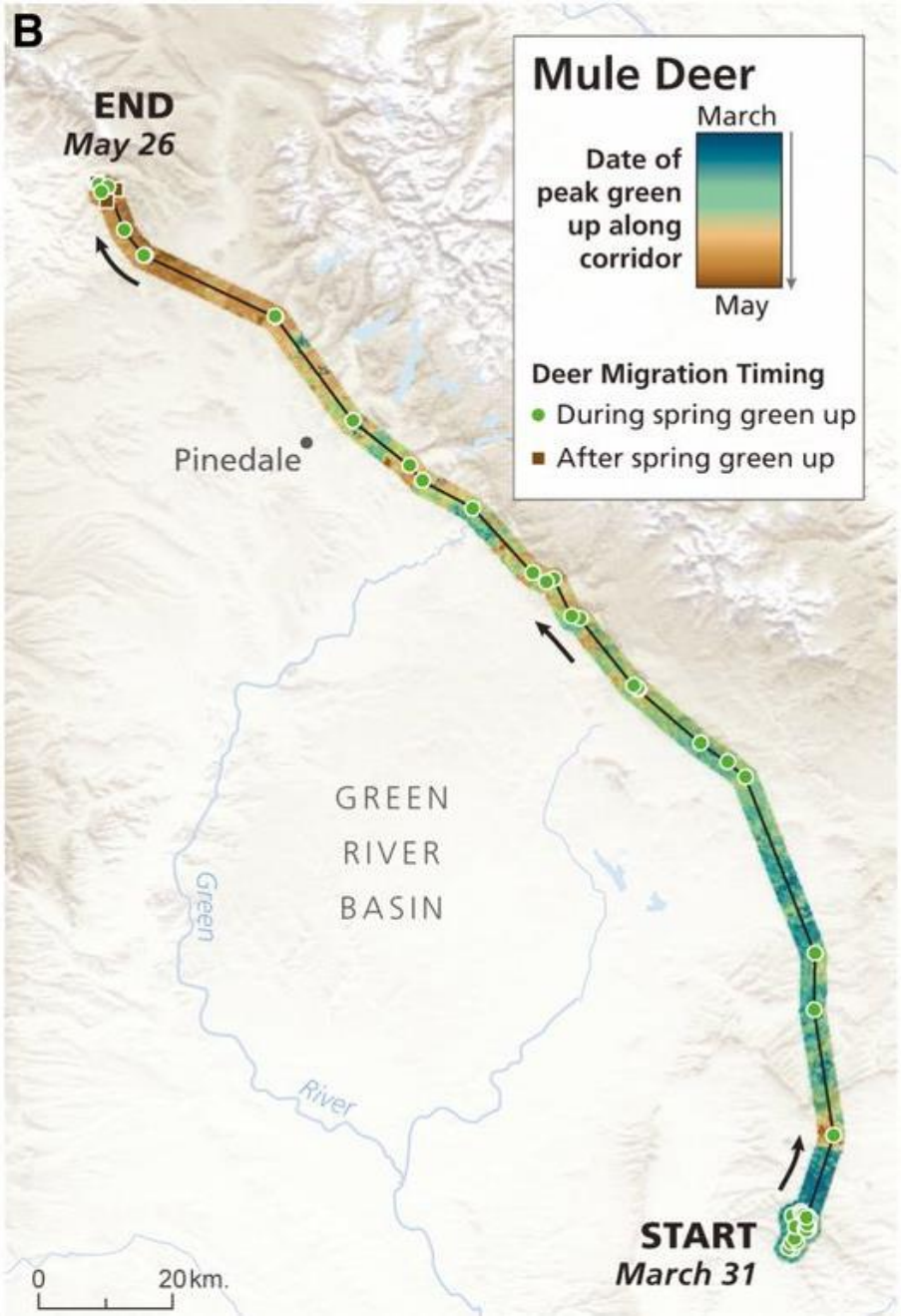
Coyote in an urban environment,
https://www.economist.com/img/b/1280/720/90/sites/default/files/20200118_USP002.jpg

Variance and HR: examples

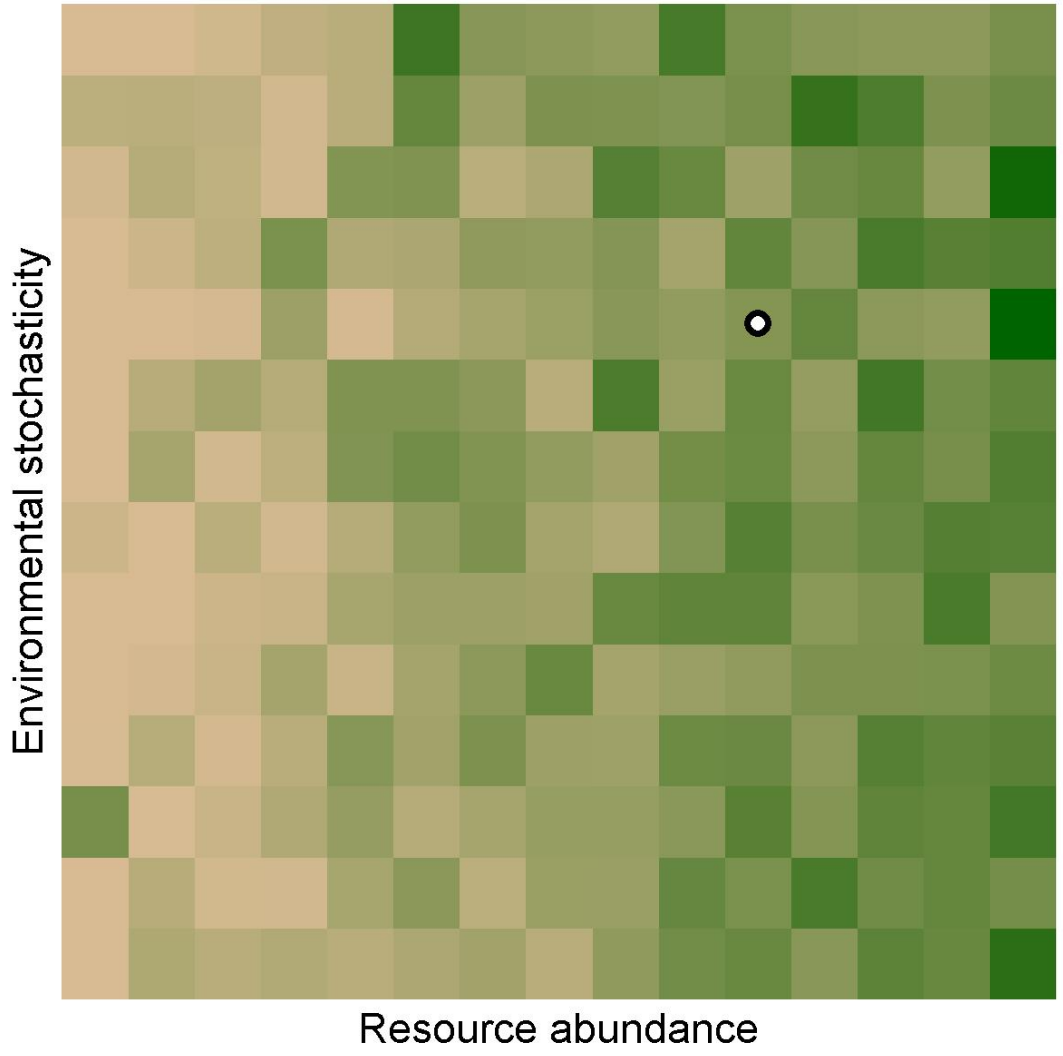
- A deer surfs the green wave

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

(Geremia et al. 2019)



Variance and HR: simulating movement



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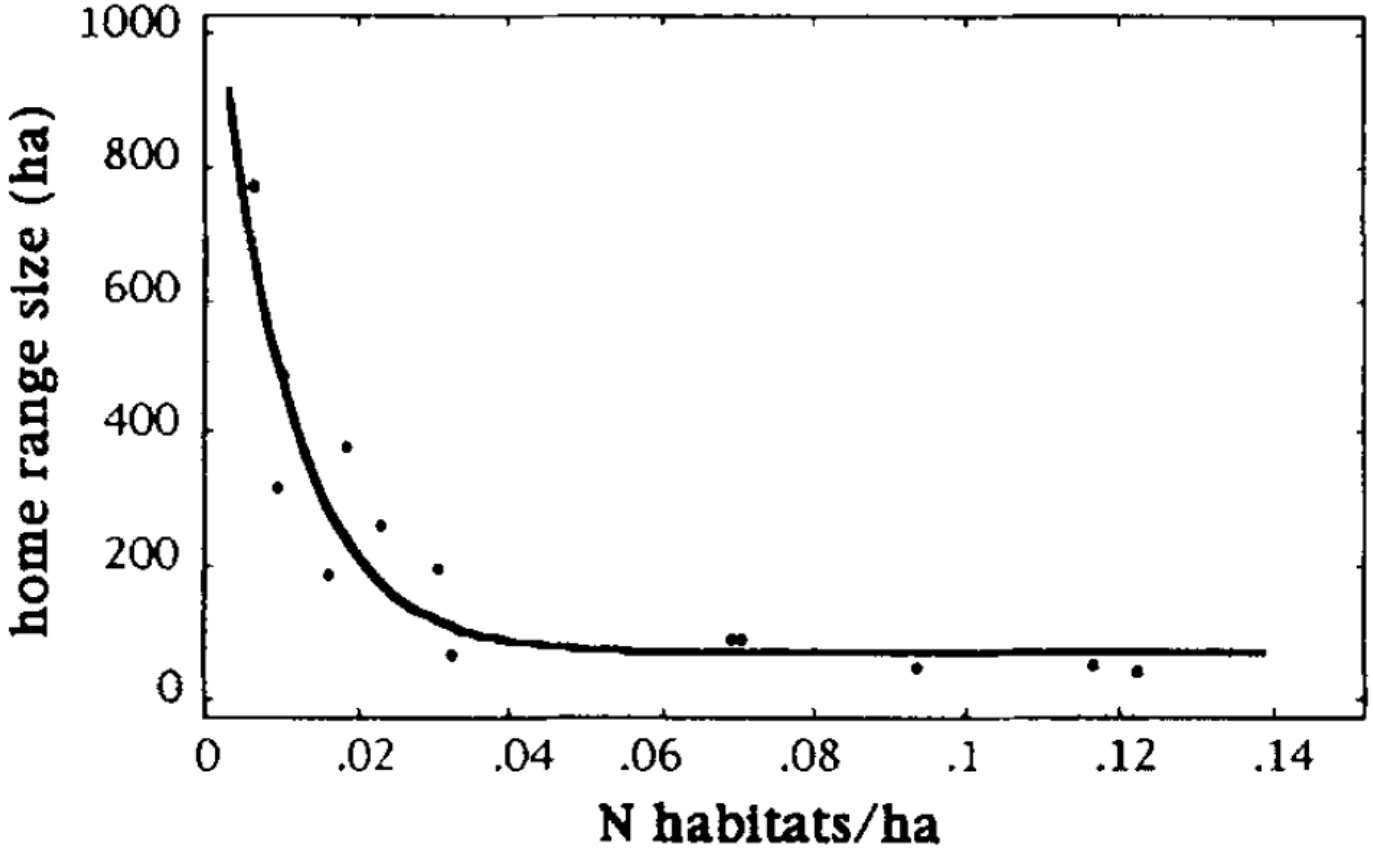
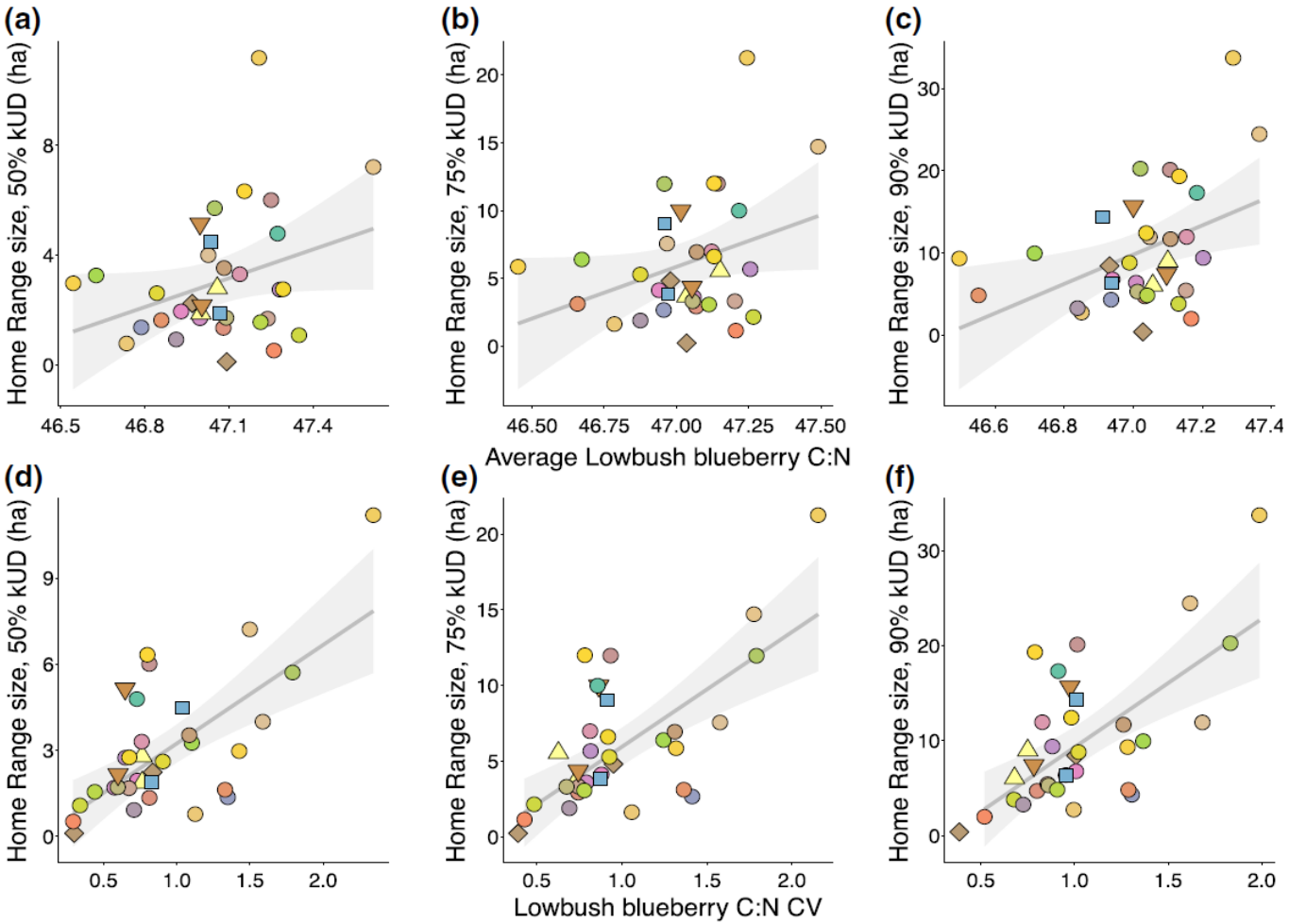


(Lucherini & Lovari 1996)

Red fox, photo by Airwolfhound

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

Wolverine, photo by Zefram

Bobcat, photo by Bill W. Ca

Canadian lynx,
photo by Michael Zahra

Coyote,
photo by Yathin S. Krishnappa

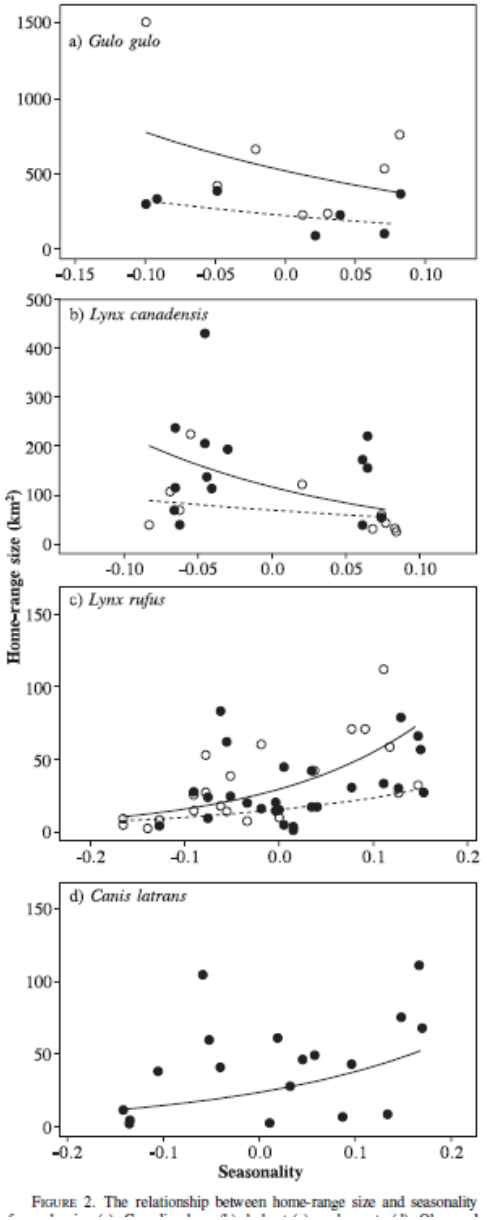


FIGURE 2. The relationship between home-range size and seasonality

(Nilsen et al. 2005)

Variance and HR: examples in literature

Wolf, photo by Daniel Mott

Fisher,
photo by Douglas H. Domedion

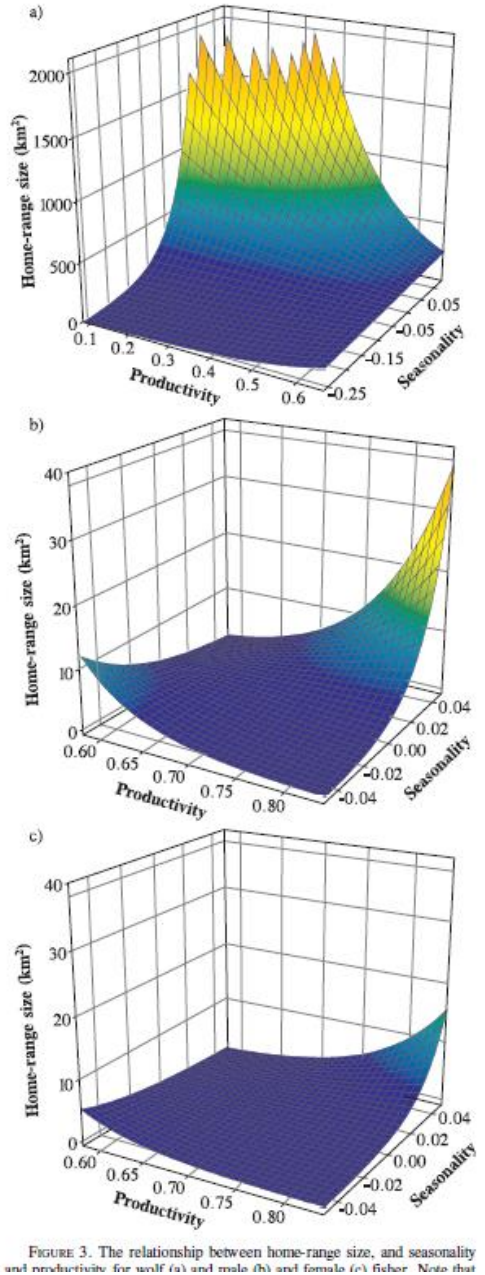


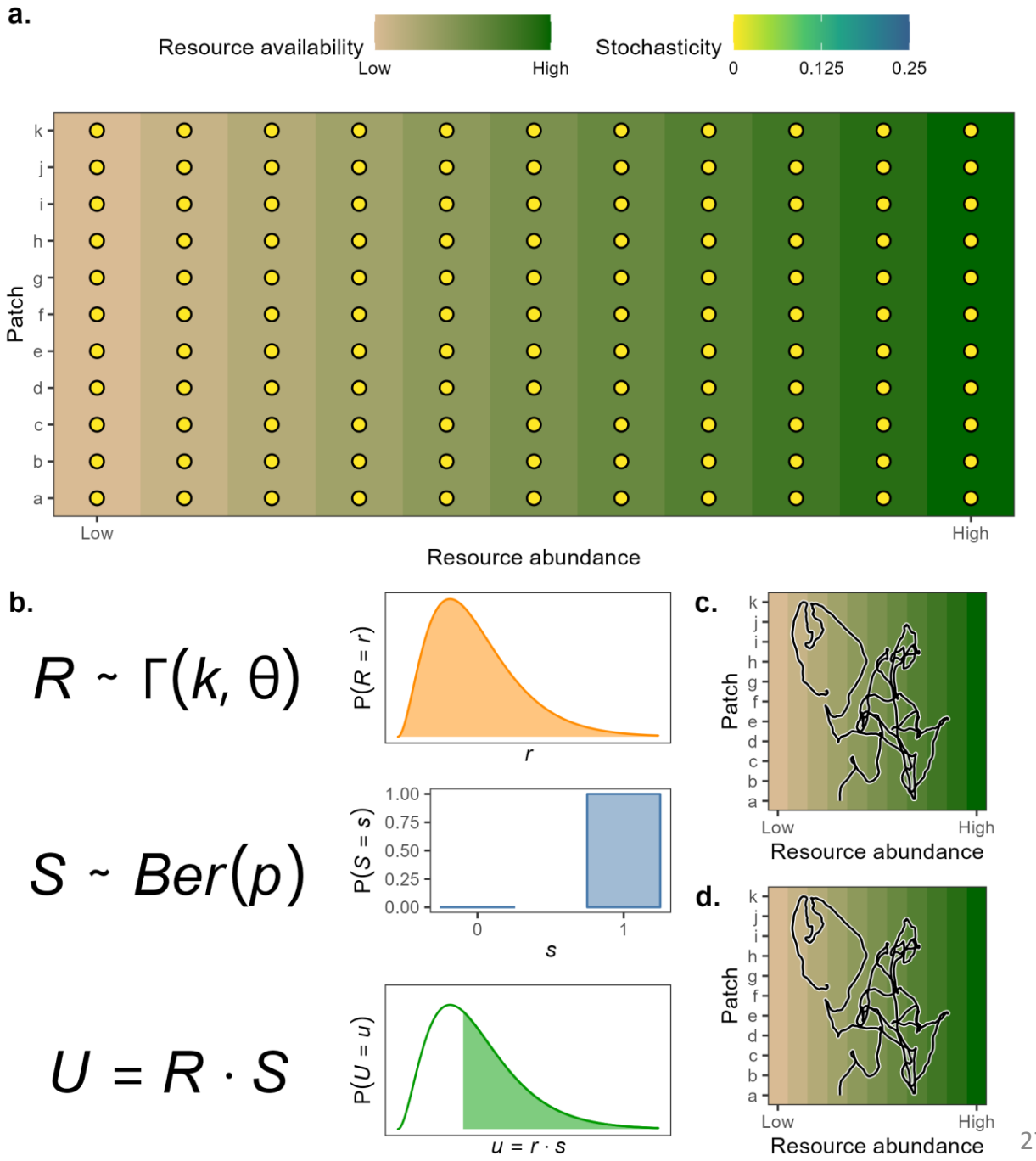
FIGURE 3. The relationship between home-range size, and seasonality and productivity, for wolf (a) and male (b) and female (c) fisher. Note that

(Nilsen et al. 2005)

Stable environments --> stable needs

In predictable environments:

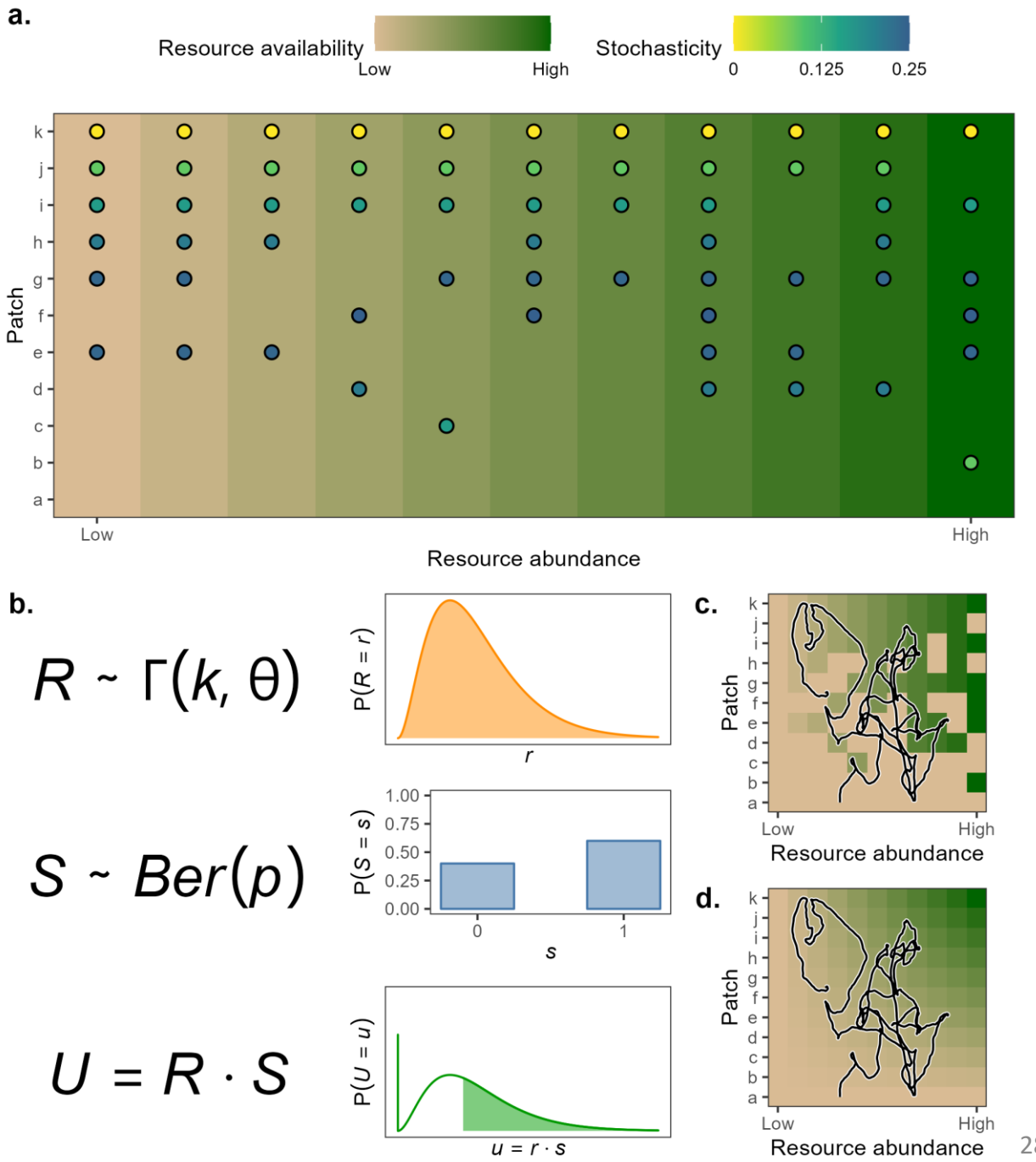
- P(success) = 1 (no failures)
- Availability = Abundance
- Prefer high-abundance areas
- $U = R \times S = R \times 1 = R$
- $\mathbb{E}(U) = R \times \mathbb{E}(S) = R \times 1 = R$



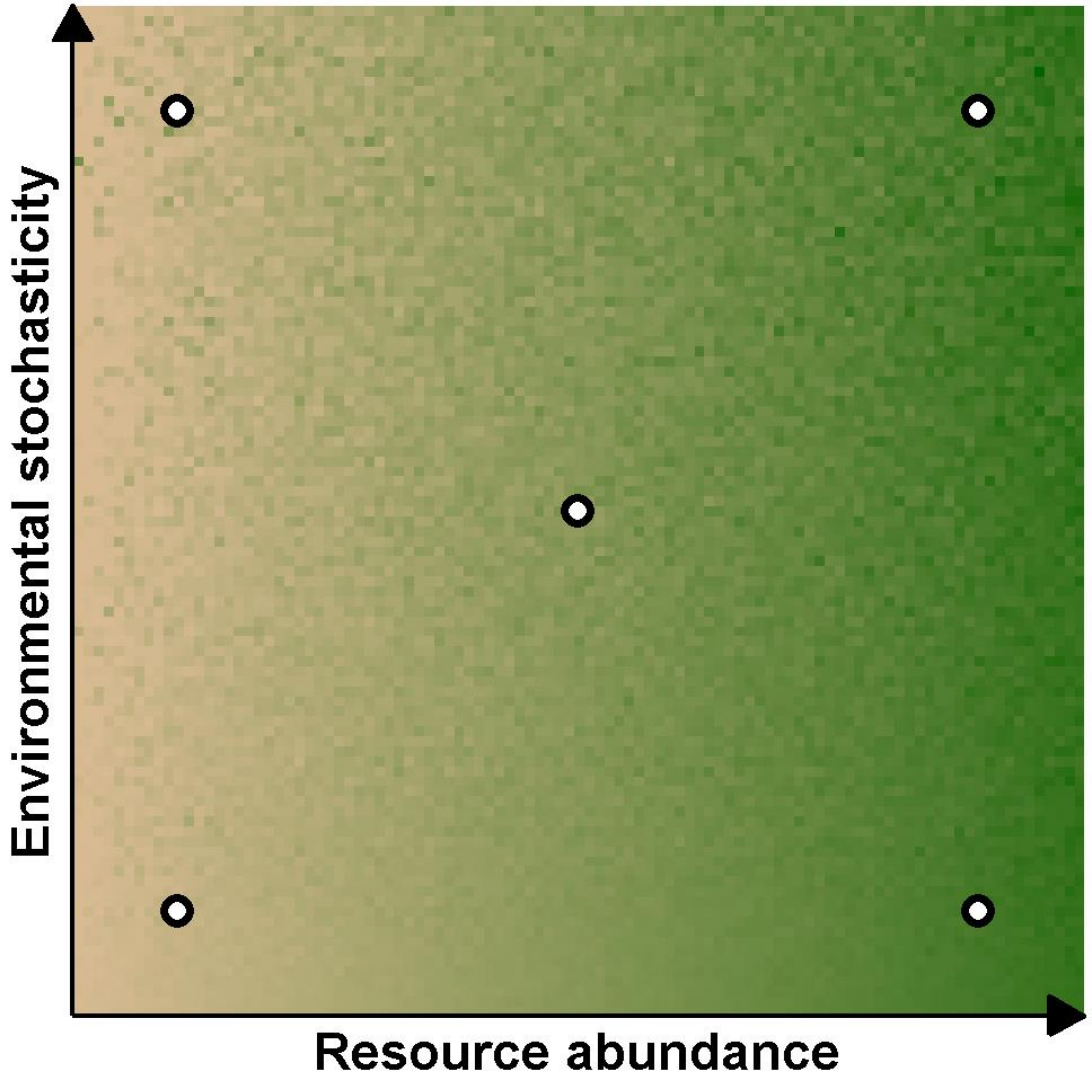
Variable environments --> variable needs

In unpredictable environments:

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

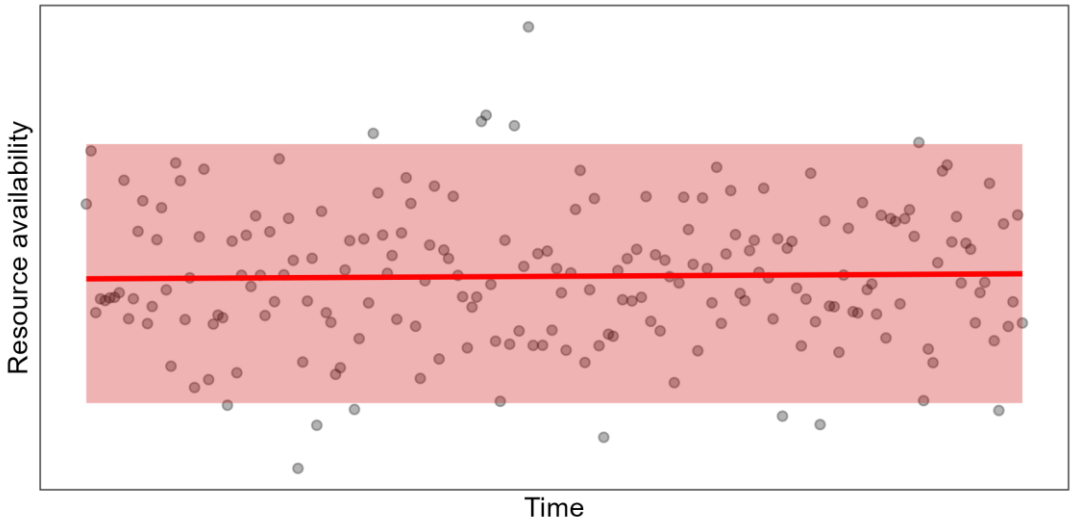


Abundance, variance and HR: simulating movement

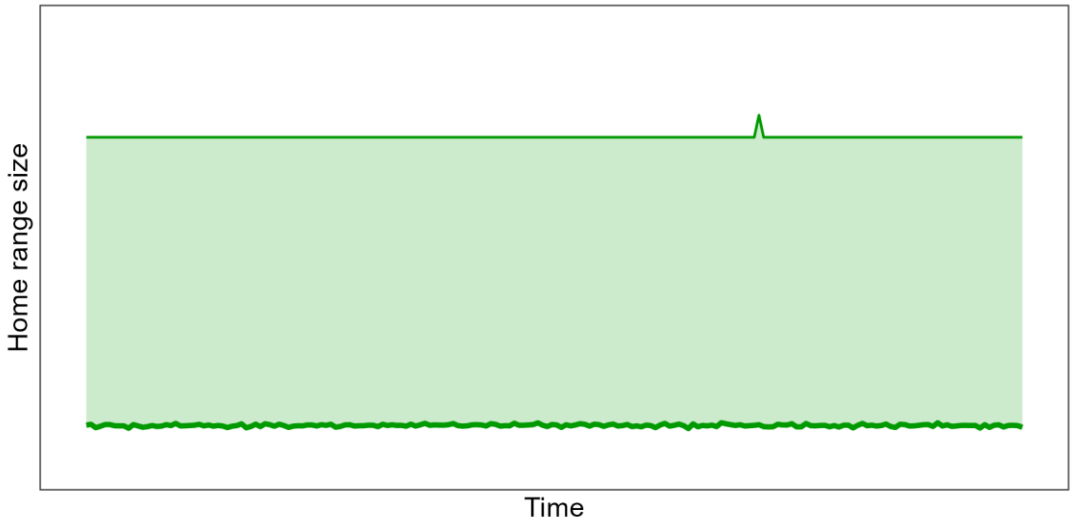


Stationary environments --> constant HR

- Constant mean
- Constant variance

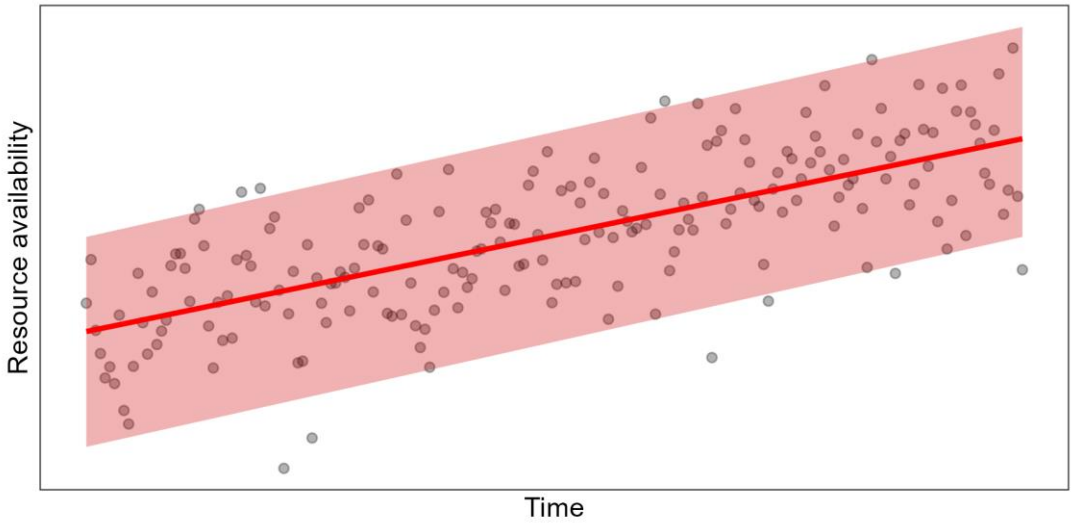


- HR remains constant over time

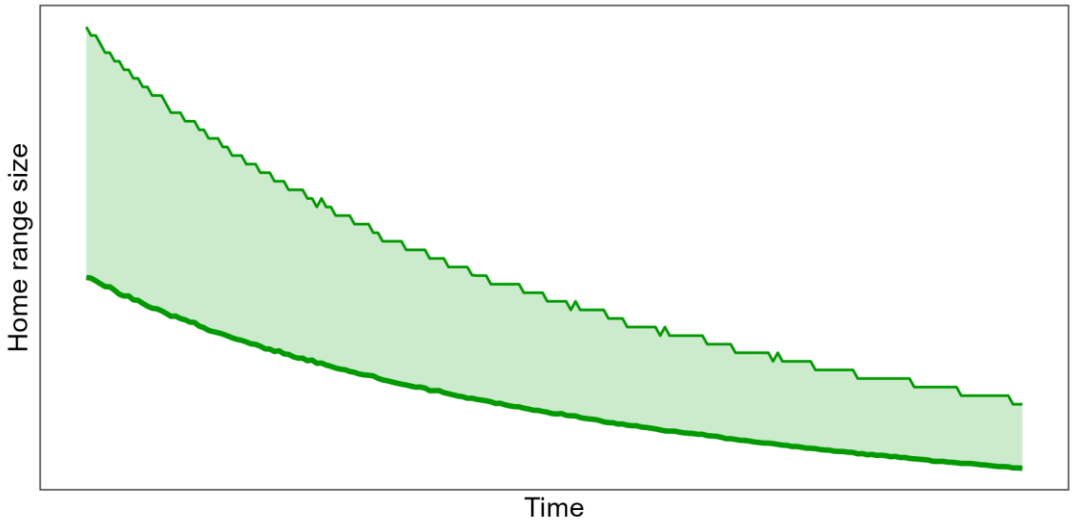


Changing mean --> HR changes rapidly

- Linearly increasing mean
- Constant variance

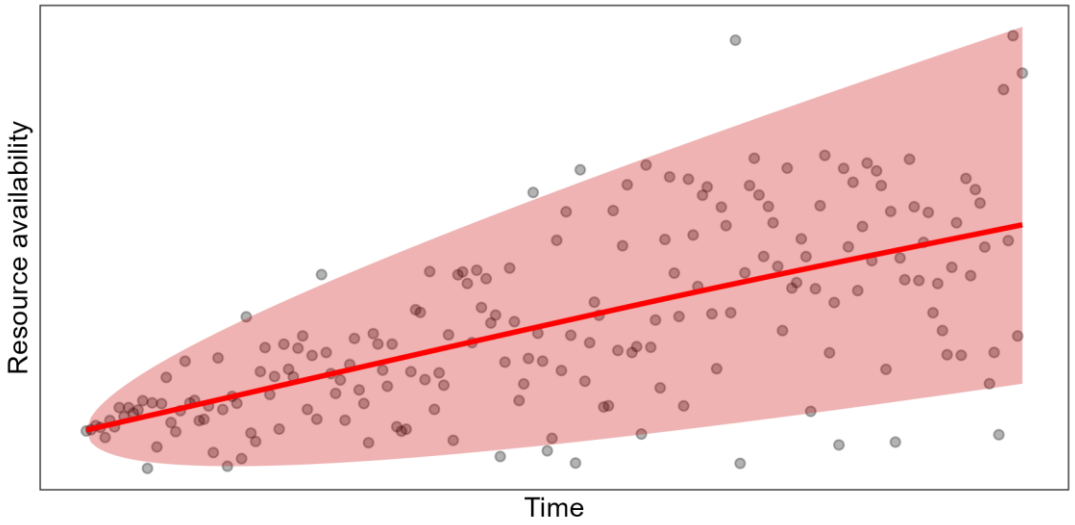


- HR ∝ 1/availability
- 95% HR decreases faster

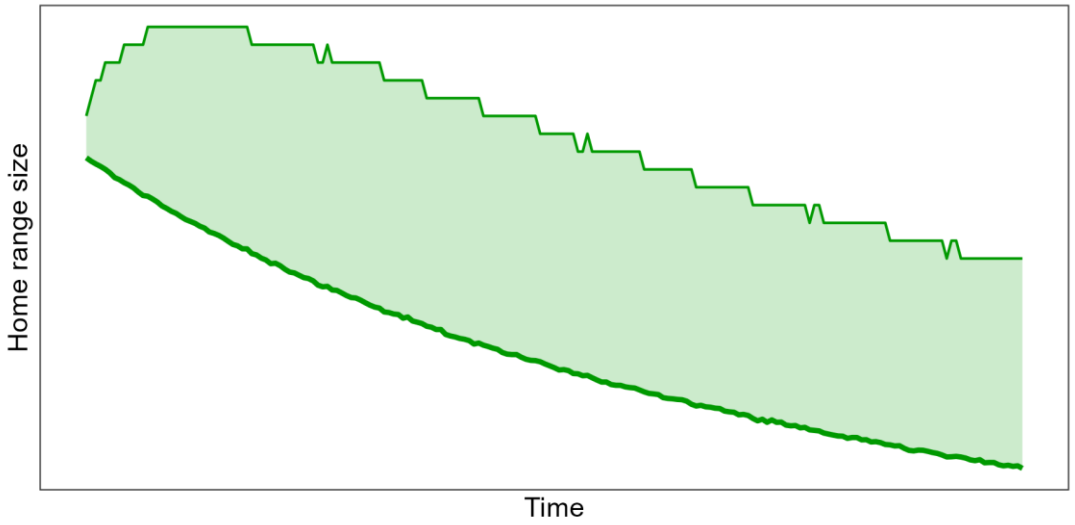


Changing mean and variance --> HR can change slowly

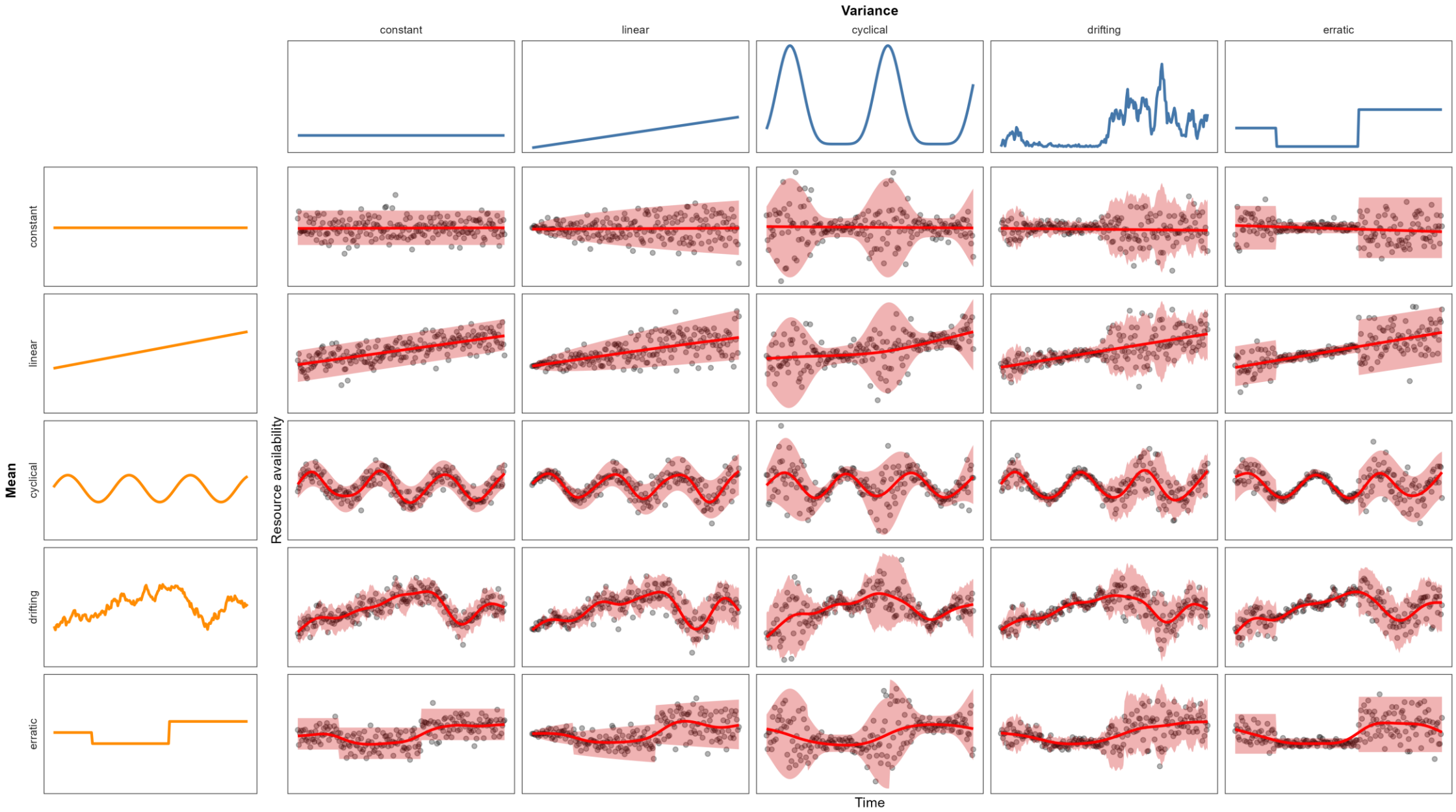
- Linearly increasing mean
- Linearly increasing variance



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



Relationships can be complicated…



Modeling it all

- Movebank dataset:
  - > 1500 animals
  - > 75 species
- New global raster of environmental variance
- Continuous time movement models (`ctmm` R package)
- Hierarchical modeling for common trends (`mgcv` R package)

Summary

- Can measure HR as a **catch-all variable** for animal's needs
- But only if animals are **range-resident** with a **stable centroid**
- HR is affected by:
  - Resource abundance (*R*)
  - Environmental variance and P(success)
  - $U = R \times S$ (because ***R* and *S* interact**)

Funder acknowledgements

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