Individual-based modelling in RangeShiftR

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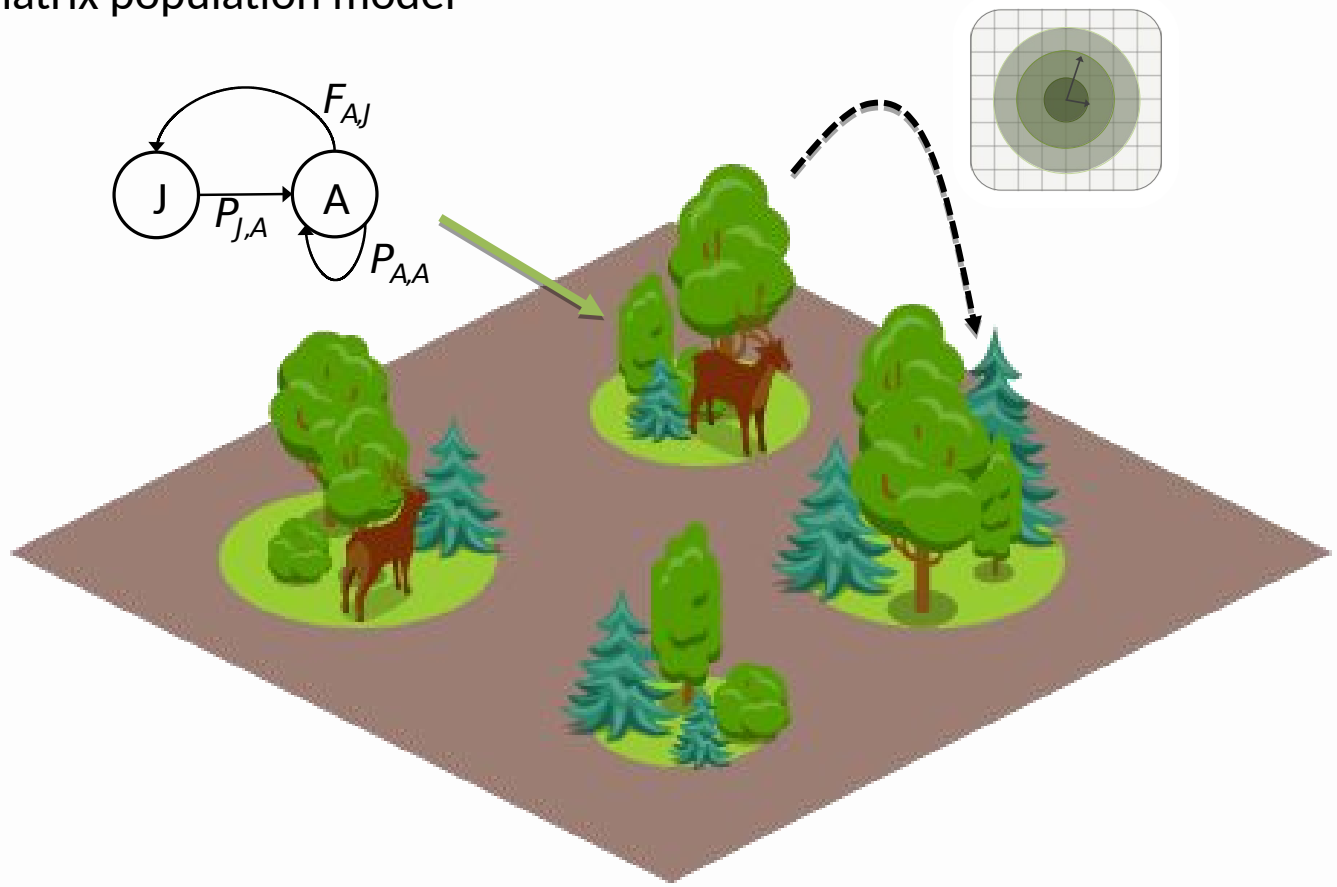
https://bit.ly/Potsdam-Macroecology

@ZurellLab

Spatially explicit population models

Local population dynamics described by population model, e.g. logistic growth or matrix population model

Dispersal described by dispersal kernel or movement simulator



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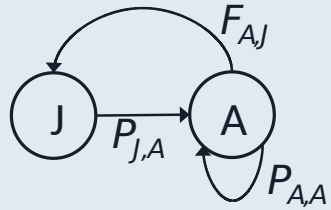

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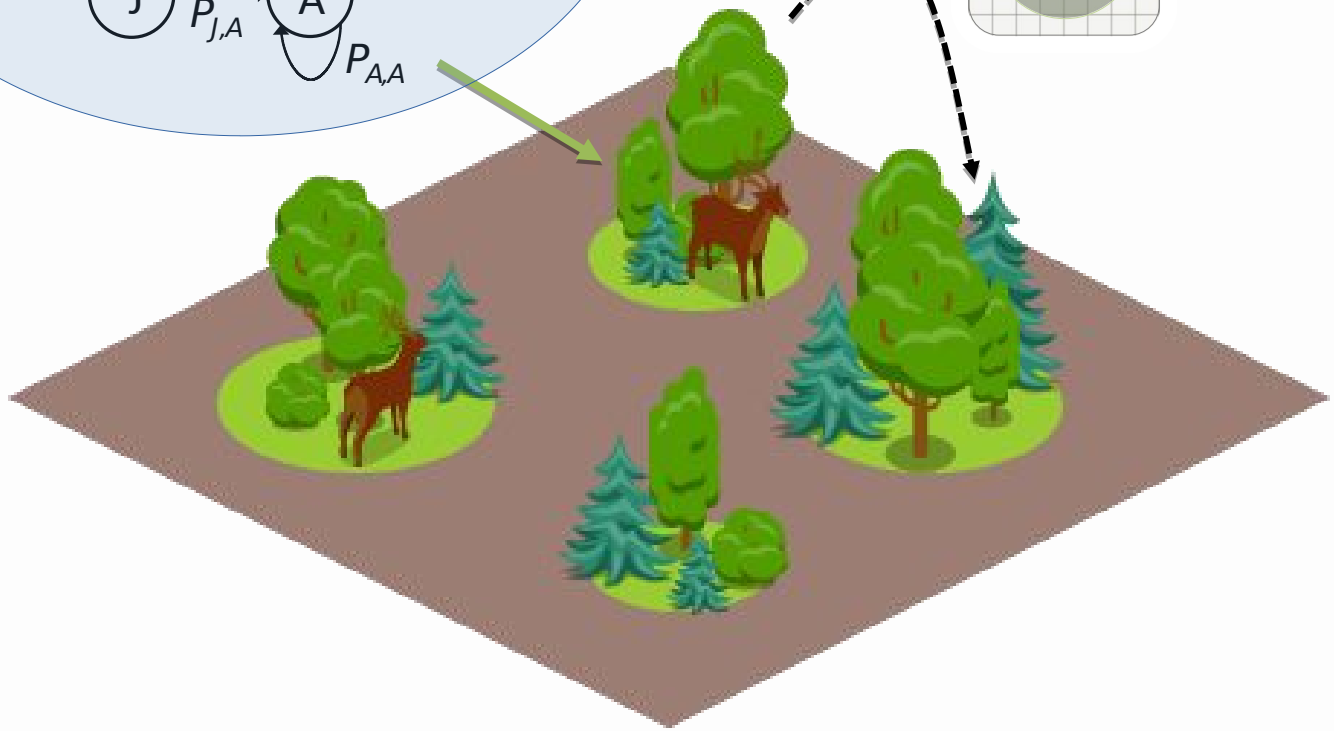

RangeShiftR – local population dynamics

- Stage-structured population:
  - Life cycle can be described by subsequential developmental stages
  - Rates are defined w.r.t. to a fixed-length time step (usually 1 year)

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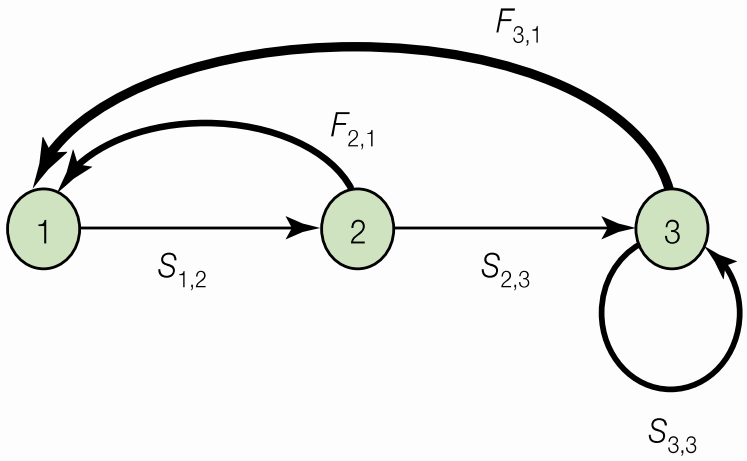
- Example:

Life-cycle graph



With (2019) Oxford Univ. Press.

Stages:

1. Juveniles - do not reproduce
2. Sub-adults - inexperienced breeders
3. Mature adults - experience breeders

Transition rates:

$F_{i,1}$ Fecundity

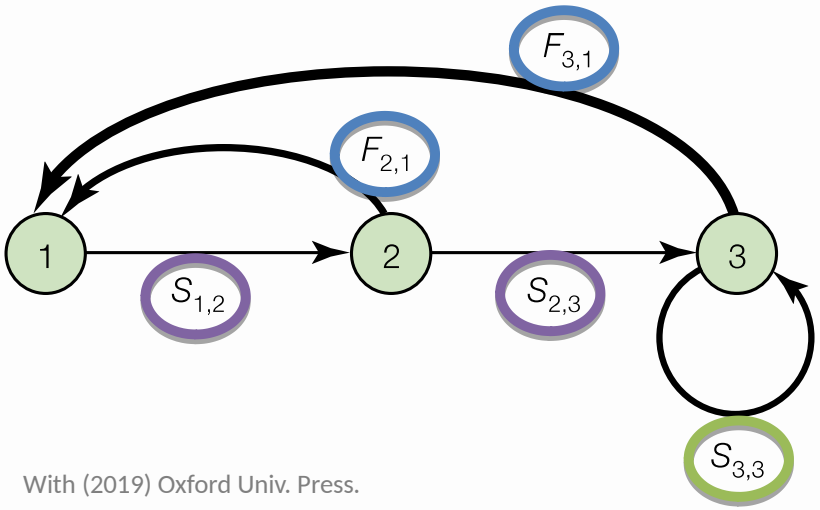
$S_{i,j}$ Development rate (transition to next stage)

$S_{i,i}$ Survival probability

RangeShiftR – local population dynamics

- Parameters provided through classical transition matrices (but applied stochastically)
  - Transition matrices can be age-structured (Leslie matrix) or stage-structured (Lefkovitch matrix)

Life-cycle graph:



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(Lefkovitch) Transition matrix:

$$A = \begin{pmatrix} S_{1,1} & F_{2,1} & F_{3,1} \\ S_{1,2} & S_{2,2} & 0 \\ 0 & S_{2,3} & S_{3,3} \end{pmatrix}$$

Fecundity

Survival

Development

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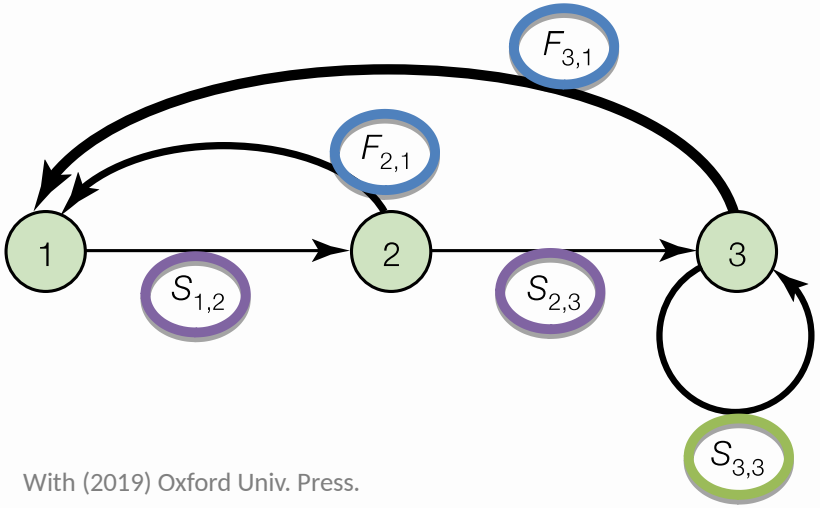

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Lynx transition matrix:

$$A_{Lynx} = \begin{pmatrix} 0 & 0 & 5.0 \\ 0.53 & 0 & 0 \\ 0 & 0.63 & 0.8 \end{pmatrix}$$

Fecundity

Survival

Development

RangeShiftR – local population dynamics

- In RangeShifter, the processes of reproduction and survival / development happen subsequentially

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  → introduce “stage 0”

  (for individuals that develop to stage 1 in the same year they are born)

$$A_{\text{Lynx, RS}} = \begin{pmatrix} 0 & 0 & 0 & 5.0 \\ 1 & 0 & 0 & 0 \\ 0 & 0.53 & 0 & 0 \\ 0 & 0 & 0.63 & 0.8 \end{pmatrix}$$

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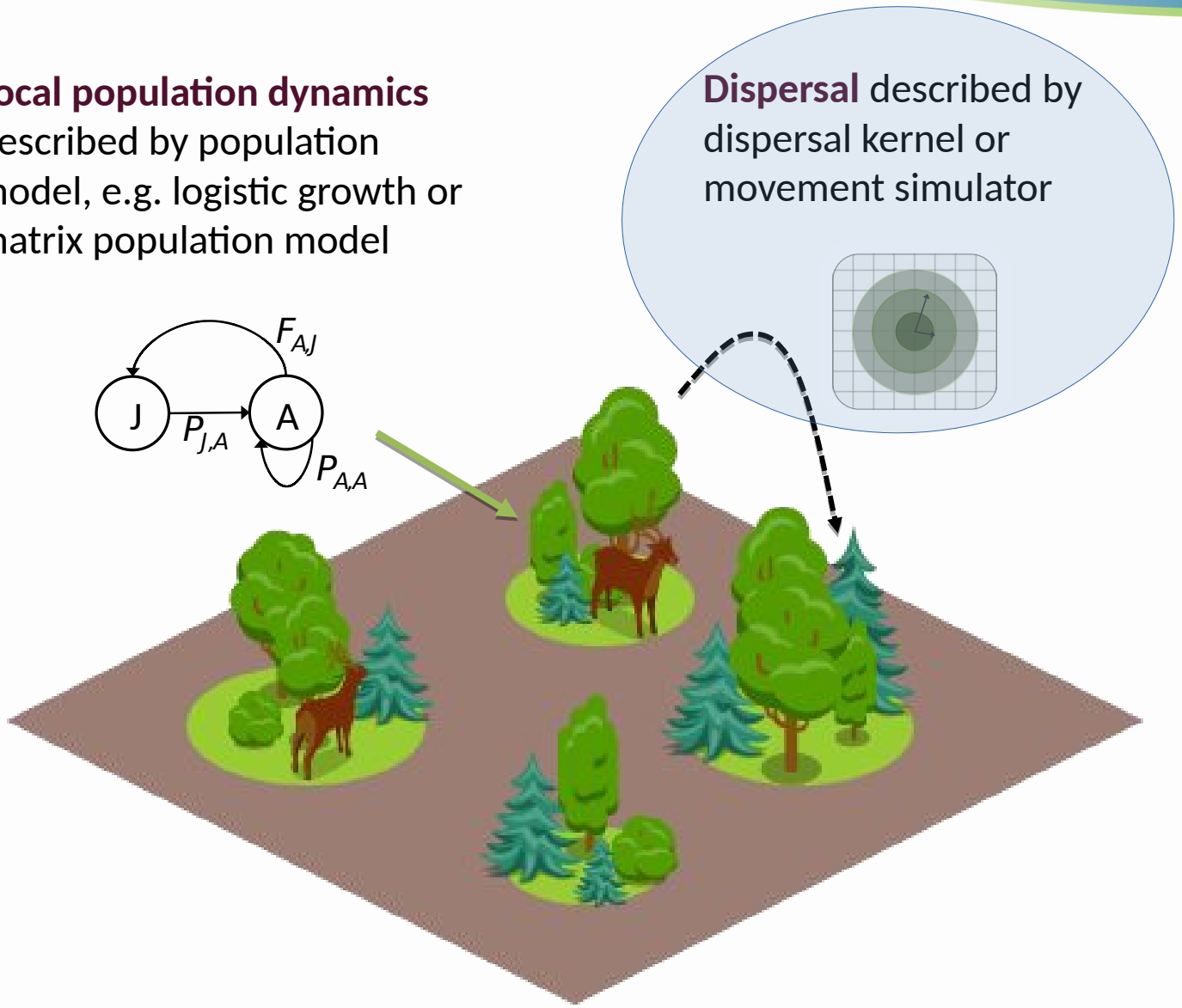
Dispersal described by dispersal kernel or movement simulator



Dispersal

- Natal/juvenile dispersal: spatial process by which individuals move away from birth location

  → avoid kin competition, exploit new resources

- Critical for range expansion and spatial gene flow

- Associated with various costs and trade-offs that determine the eventual displacement distance

  → has impacts on both population dynamics and genetics

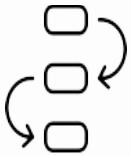
Dispersing individuals are a non-random subset of the population

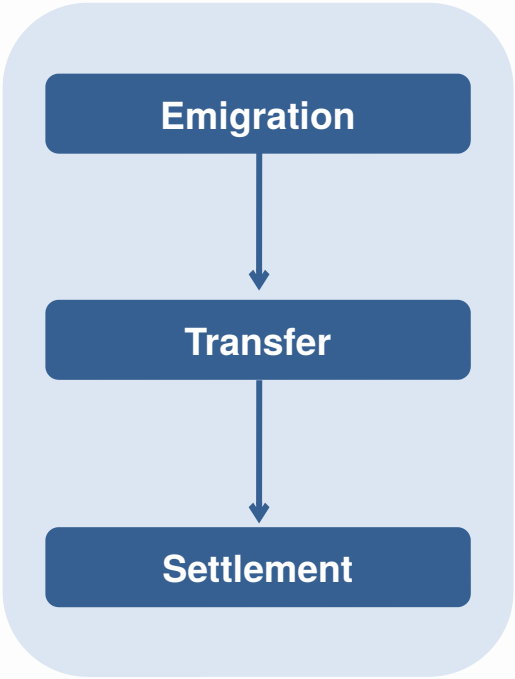
(**Left**) Dispersing females of the Glanville fritillary, Melitaea cinxia, have a higher flight metabolic rate and are more fecund than sedentary ones.

(**Right**) In Siberian jays, Perisoreus infaustus, the subordinate individuals disperse, whereas the heavier and more dominant remain in their natal territories.

Kokko & López-Sepulcre (2006) Science 313: 789-791.

RangeShiftR:
three phases of dispersal





Leaving the natal site (area where born)

Movement through the landscape

Establish in a new habitat site /area

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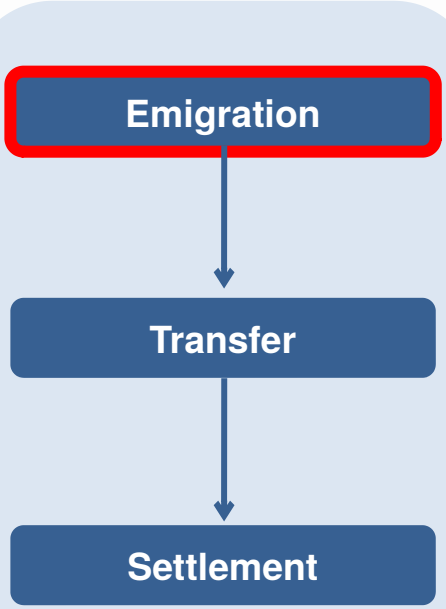

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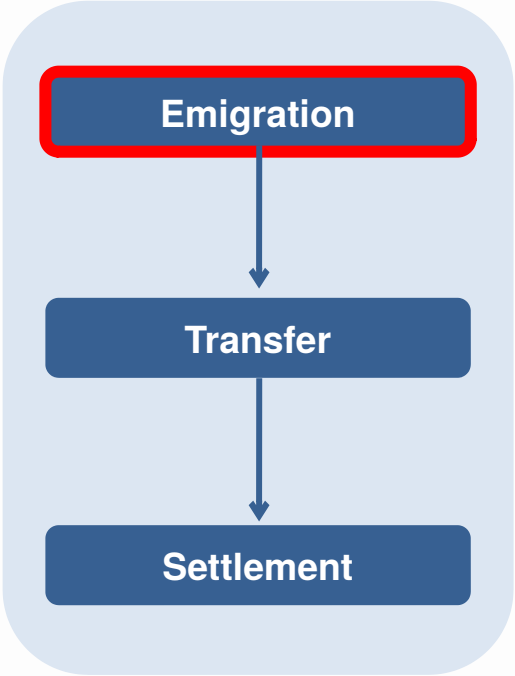
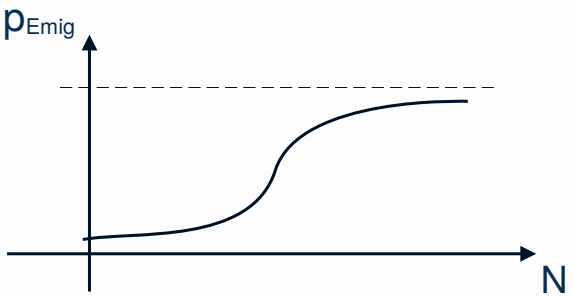


Emigration probability:

- the probability that an individual will leave its natal patch during the present year
- can be density-dependent



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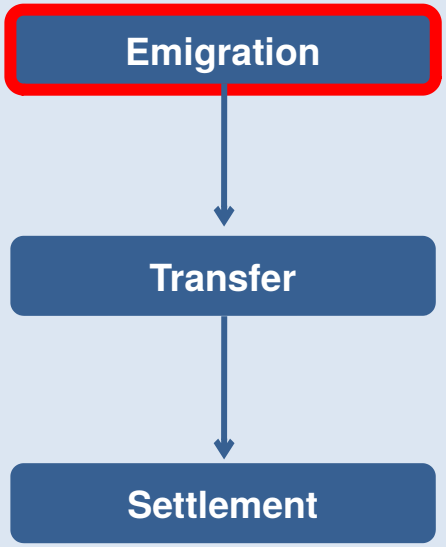

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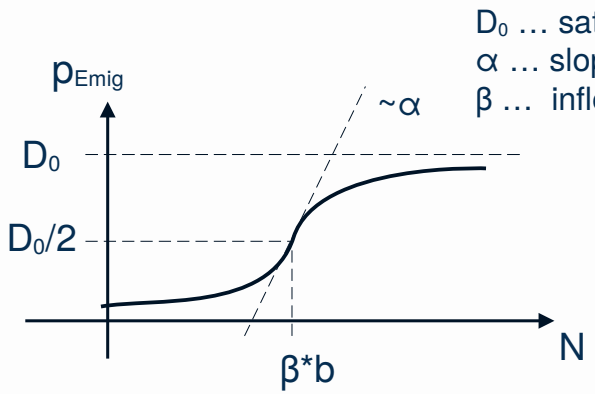

stage	sex	D_0	α	β
0	0	0.4	10	1
0	1	0.9	10	1
…	…	…	…	…

sex = 0 … female
sex = 1 … male

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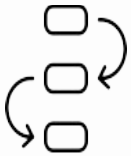
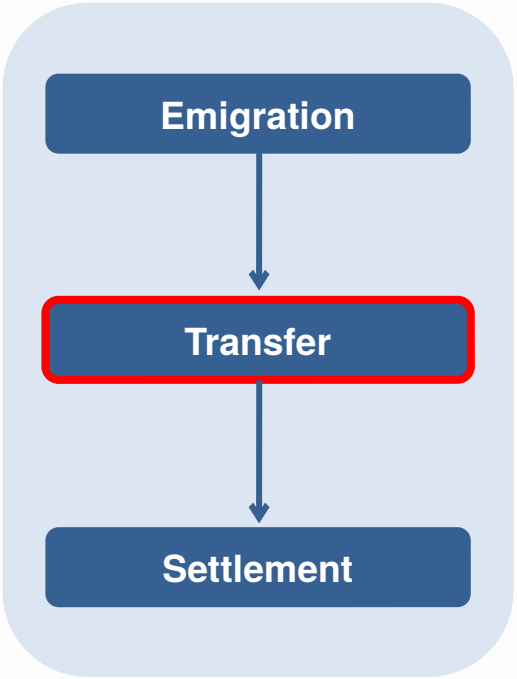
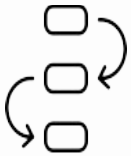
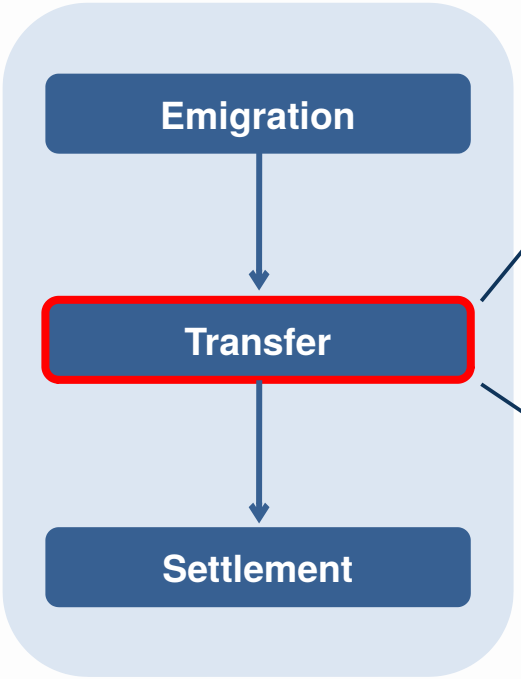




Movement through the landscape

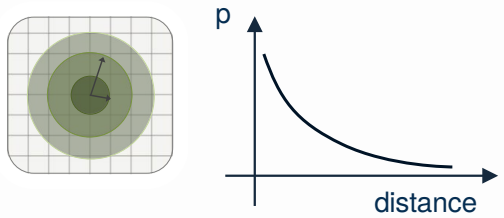
RangeShiftR: three phases of dispersal





Phenomenological models

e.g. Dispersal Kernel



Mechanistic models

e.g. Movement models:
step-wise processes that take perception and movement costs into account

RangeShiftR: mechanistic movement models

1.) Stochastic Movement Simulator

- step-wise process

Movement costs

3	4	1	0	0
1	1	3	3	5
2	3	1	1	4
1	1	0	0	0
5	4	1	0	0

Habitat cell

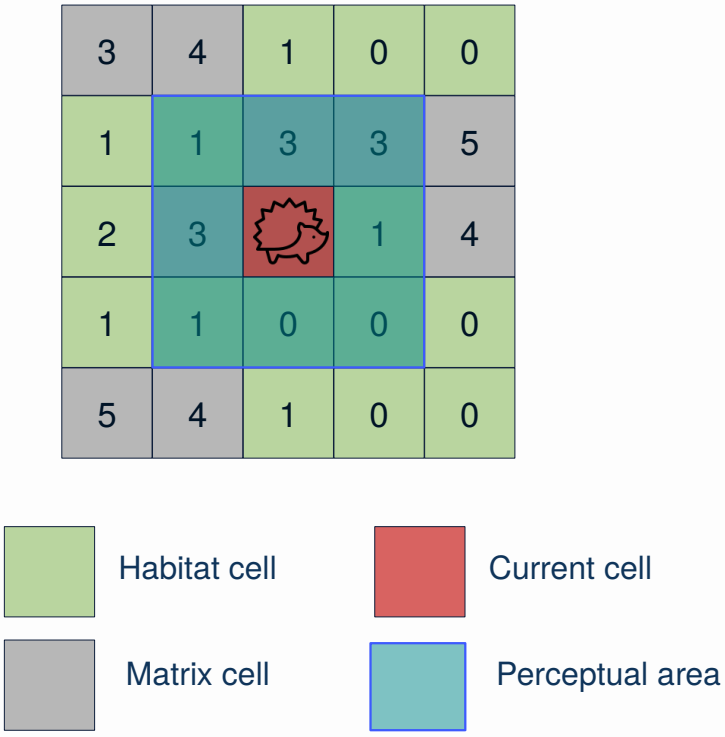
Matrix cell

RangeShiftR: mechanistic movement models

1.) Stochastic Movement Simulator

- step-wise process
- takes perception into account
  - perceptual range (e.g. 1 cell)

Movement costs

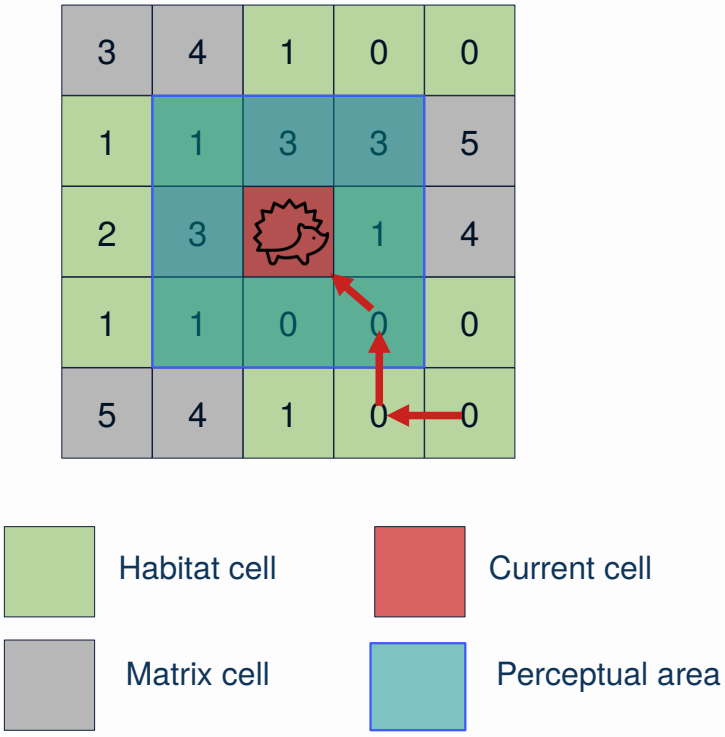


RangeShiftR: mechanistic movement models

1.) Stochastic Movement Simulator

- step-wise process
- takes perception into account
  - perceptual range (e.g. 1 cell)
- decision of next direction based on:
  - lowest average cost
  - preceeding steps in memory (e.g. 3 steps)
  - directional persistence

Movement costs



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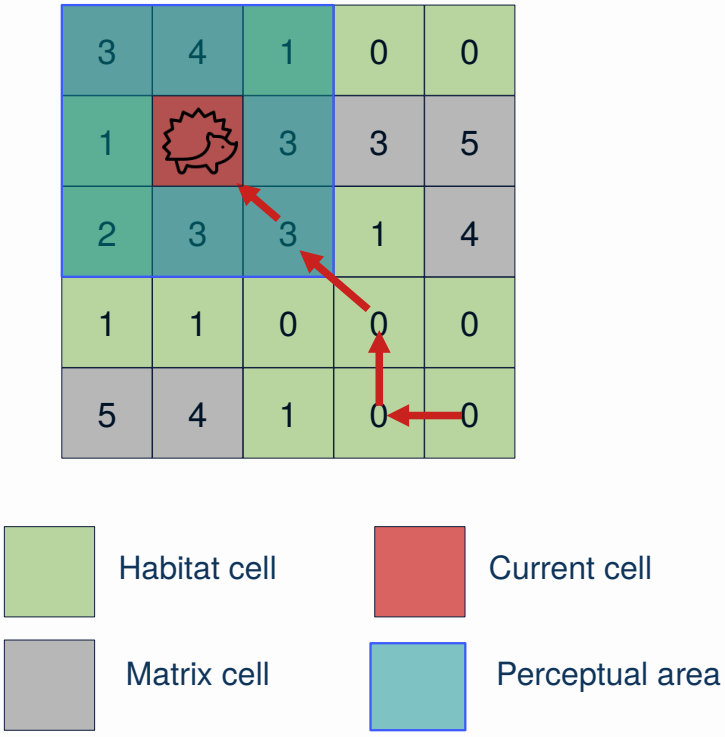

RangeShiftR:
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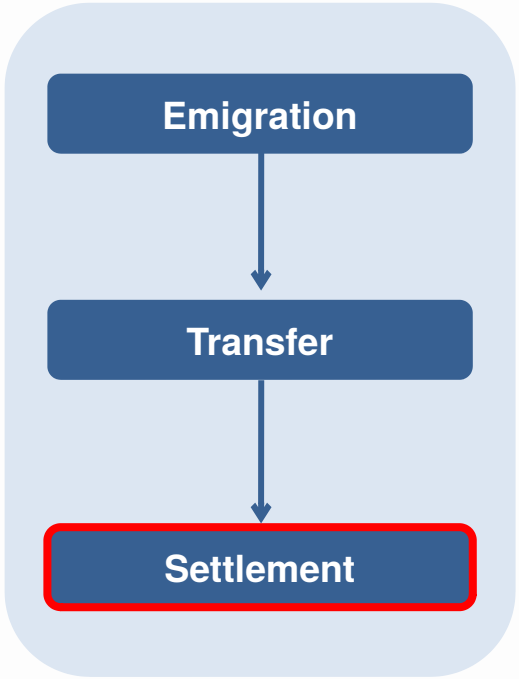
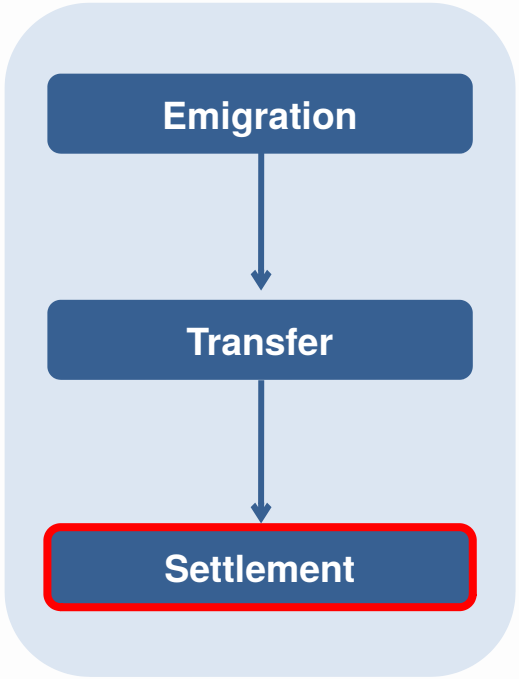


Establish in a new habitat site /area

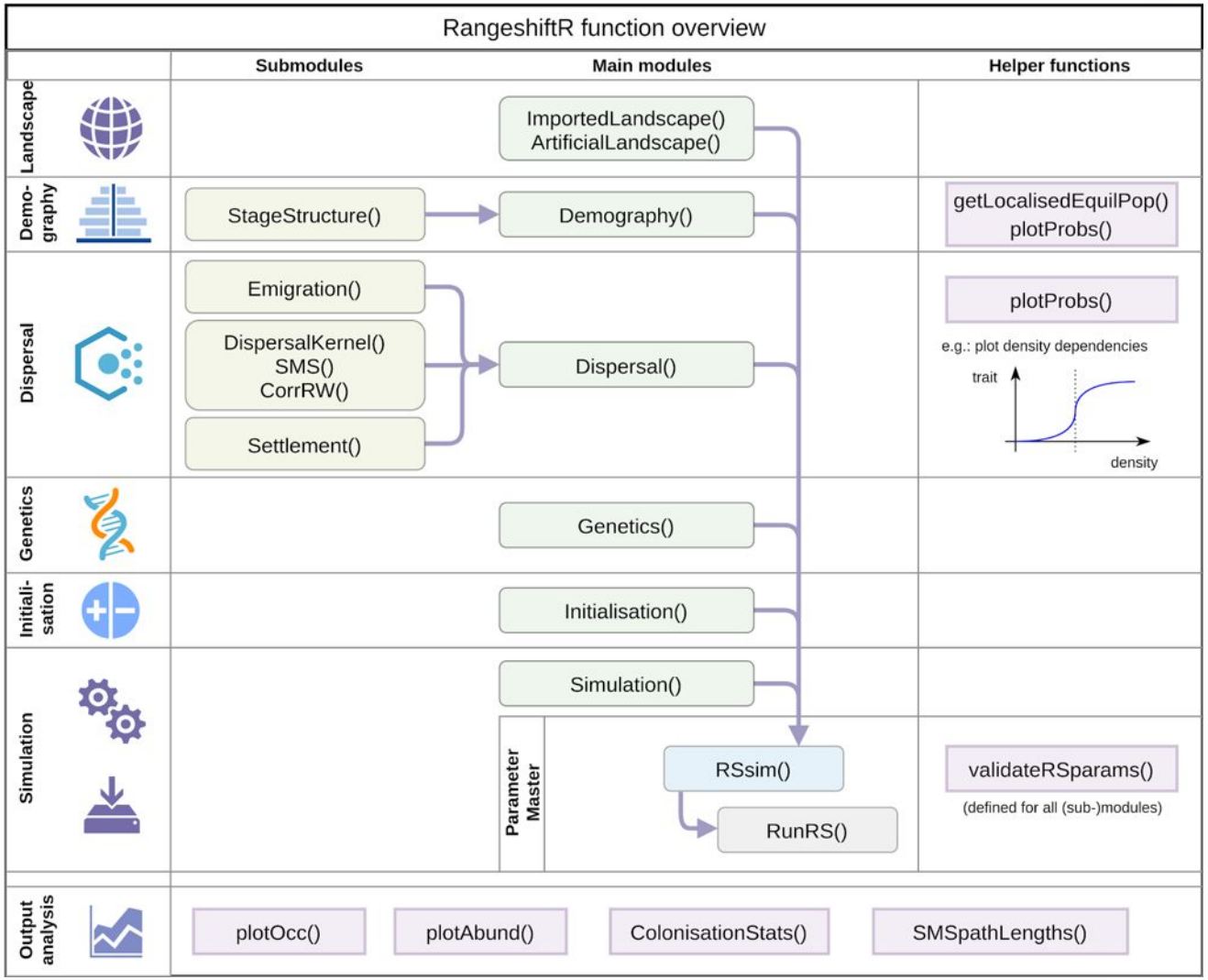
RangeShiftR: three phases of dispersal



Settlement probability:

- the probability that an individual will stay in a new habitat patch
- can be density-dependent (analogous to emigration probability)

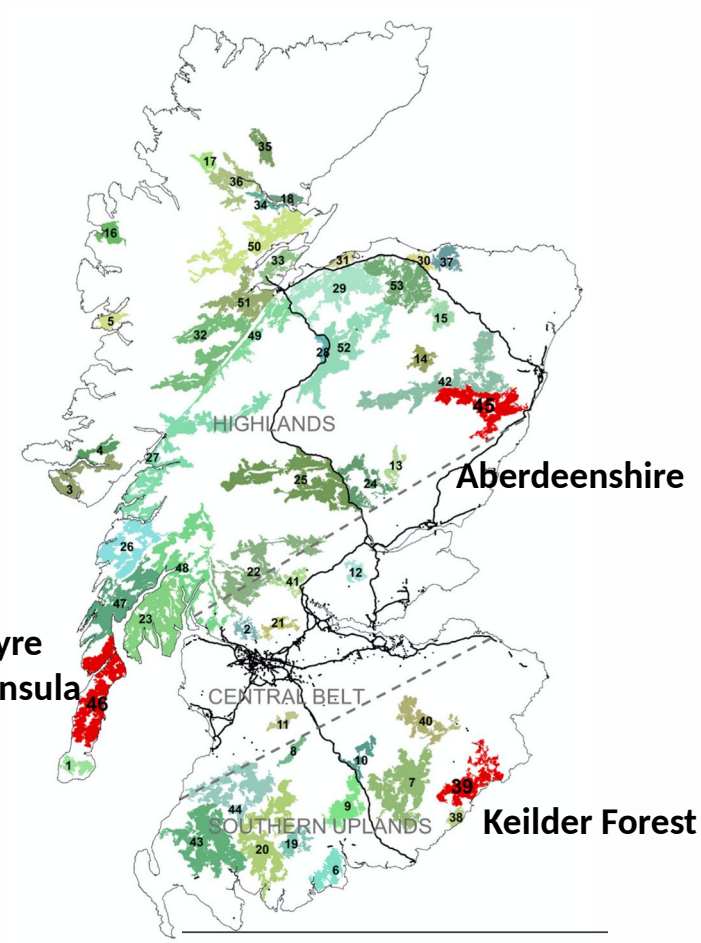
RangeShiftR overview

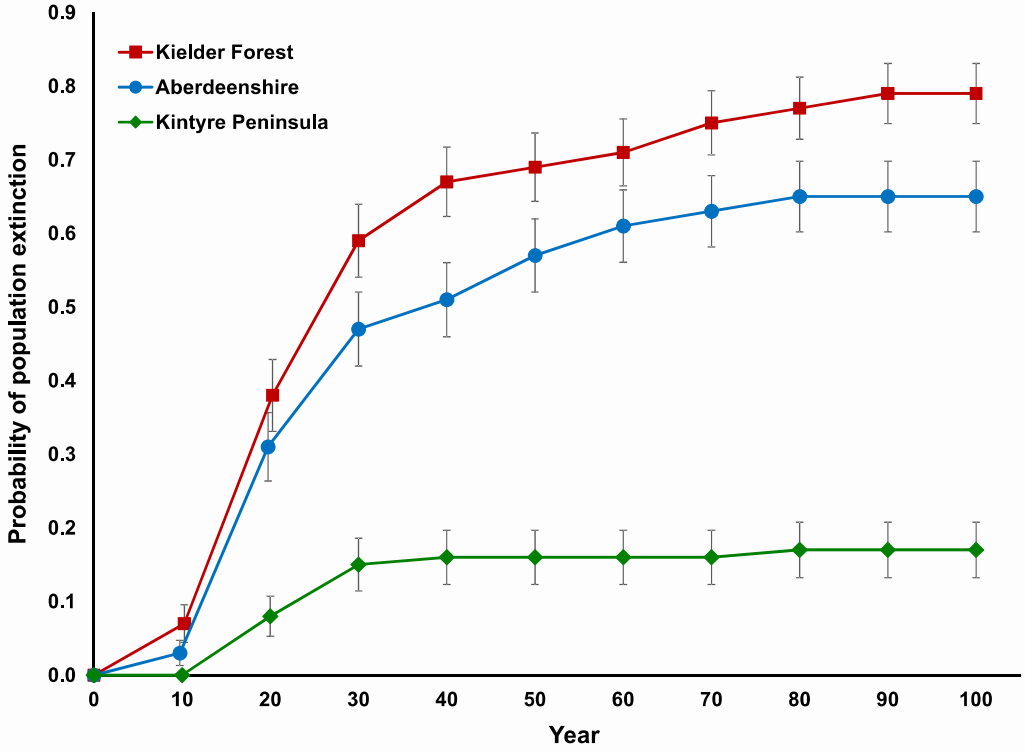


Malchow et al. (2021) Ecography. DOI: 10.1111/ecog.05689 .
Building on Bocedi et al. (2014) Methods Ecol Evol 5: 388-396. & Bocedi et al. (2021) Ecography. DOI: 10.1111/ecog.05687.

Example: Eurasian lynx, reintroduction Scotland

- Break-out rooms of 4-5 participants per group
- Time: 45 mins
- Script: IBS2022_RS_workshop/code/Prac2_RangeShiftR_Lynx.R





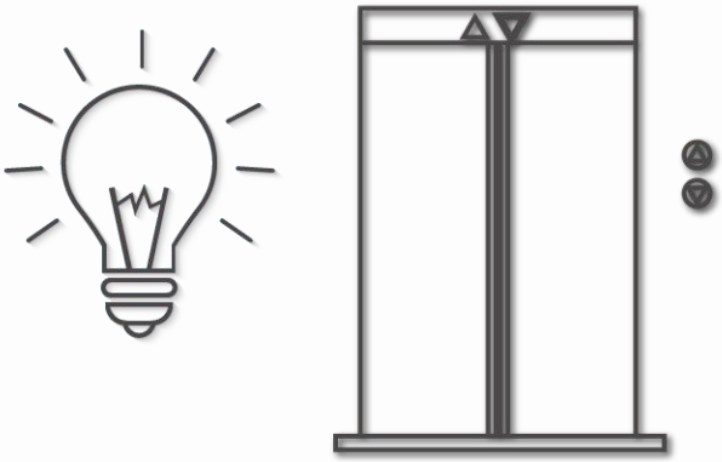
Ovenden et al. (2019) Biol Cons 234: 140-153.

Break: 15 mins

Pitch your project idea!

- In break-out rooms of 4-5 participants per group:
- Discuss your own research ideas using RangeShifter !
- Prepare a 1-min elevator pitch on your Research Concept:
- Research question, species, spatial and temporal scale, data sources, …
- Time: 20 mins

- Afterwards:
- Pitch your research idea to the panel !



The RangeShifter project

Thanks for attending our workshop!

The Team:

Greta Bocedi
Steve Palmer
Justin Travis

Anne Malchow
Damaris Zurell

Our Website:

https://rangeshifter.github.io

RangeShifter 2

RangeShiftR