



Individual-based modelling in RangeShiftR

Damaris Zurell, Anne Malchow

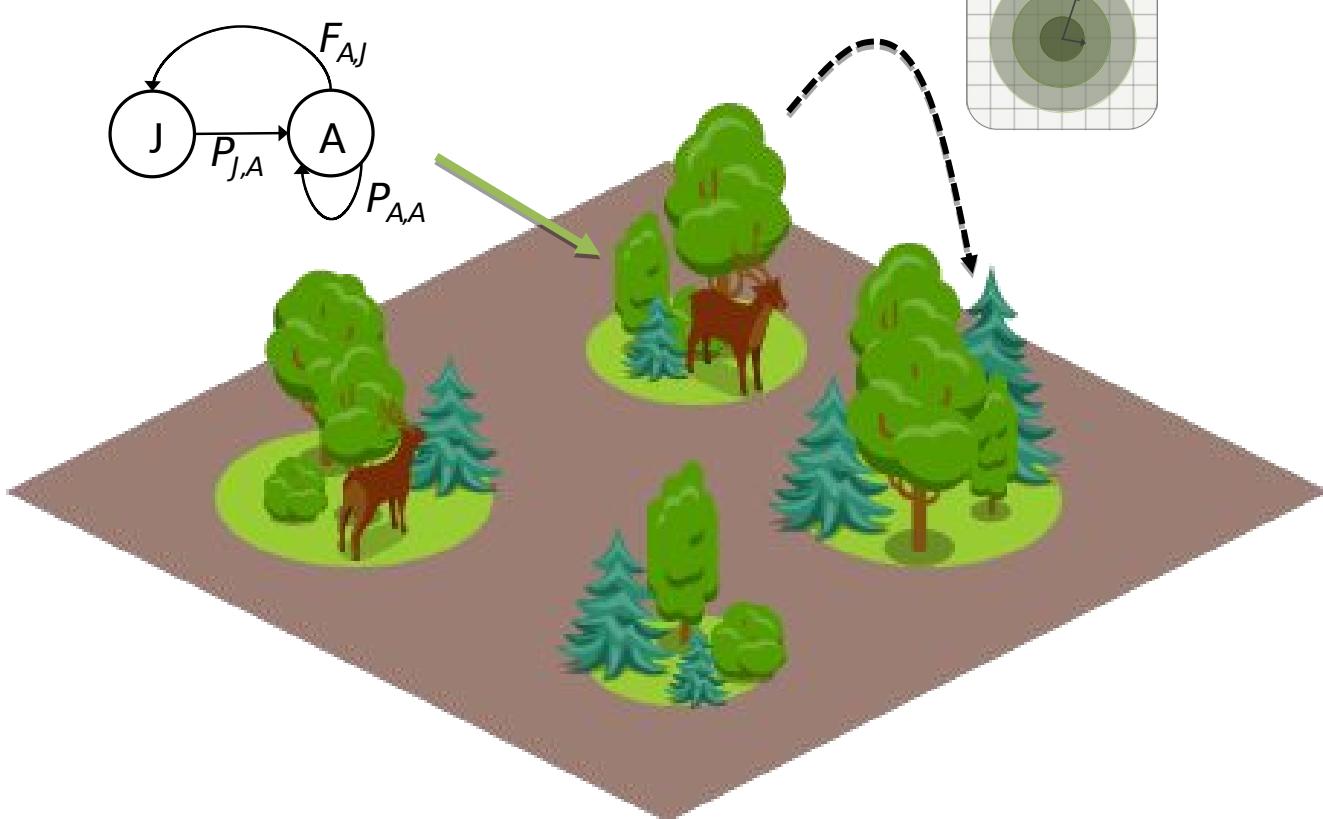
<https://damariszurell.github.io>



Spatially explicit population models

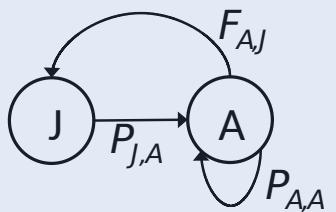
Local population dynamics
described by population
model, e.g. logistic growth or
matrix population model

Dispersal described by
dispersal kernel or
movement simulator

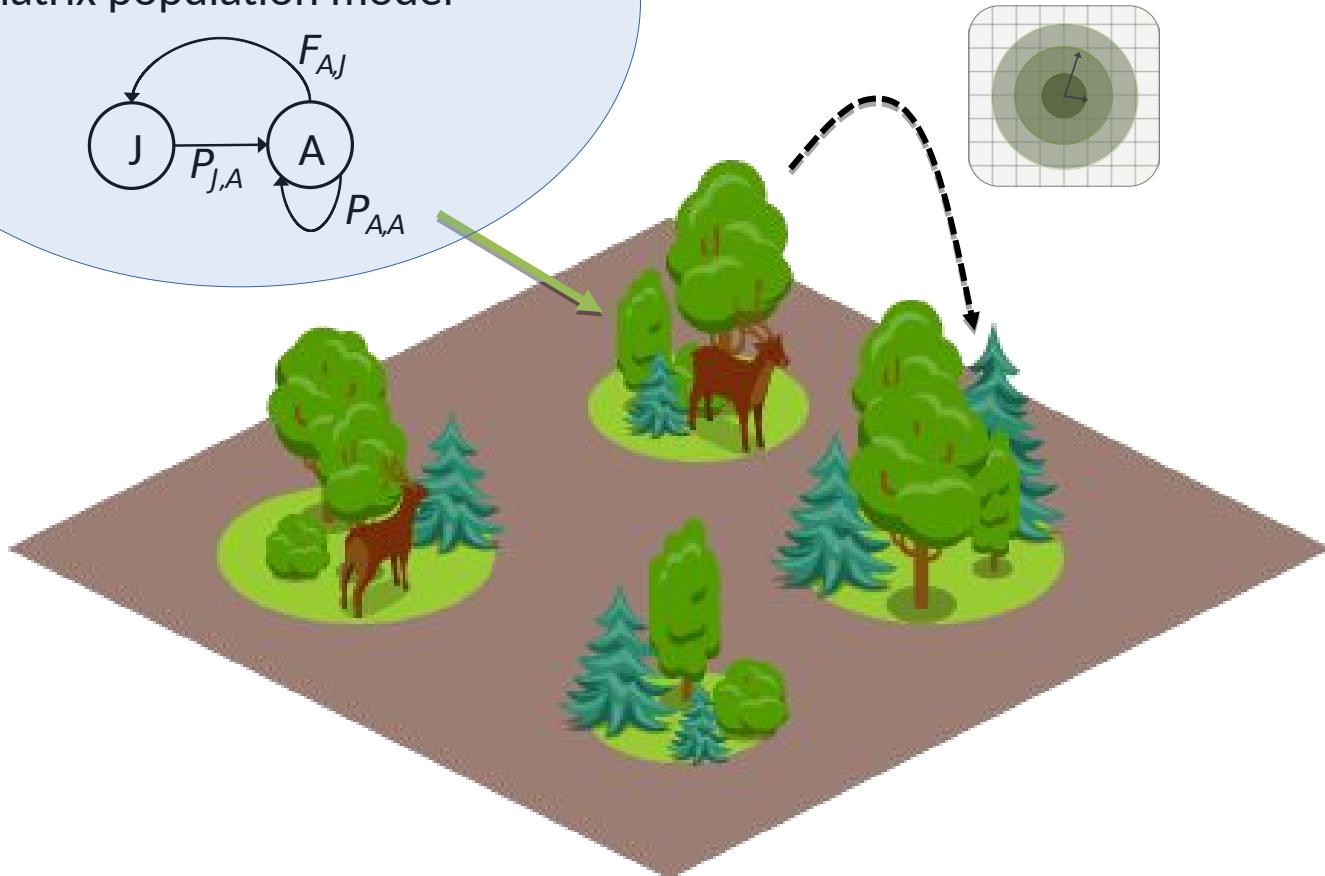


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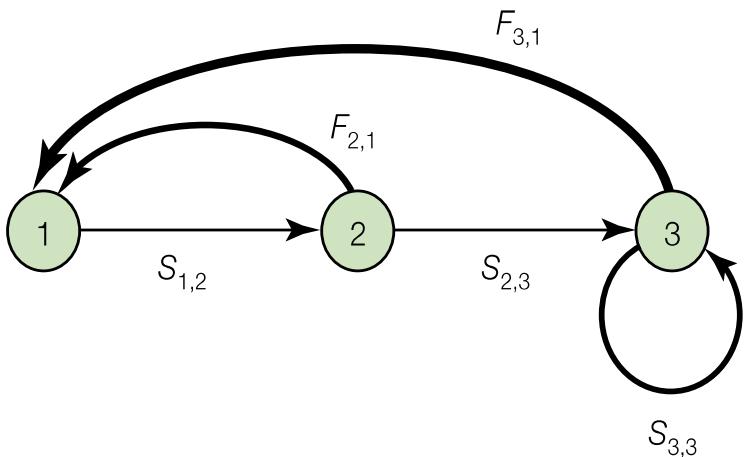
RangeShiftR – local population dynamics

- 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



Stages:

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

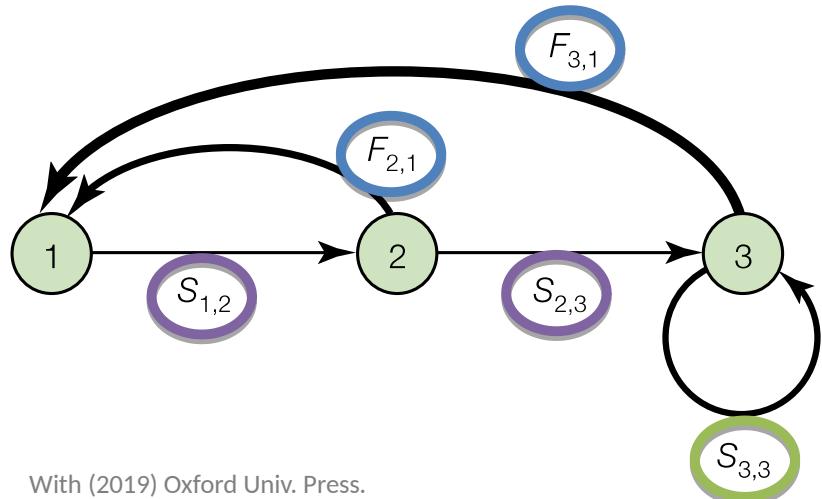
Transition rates:

- | | |
|-----------|--|
| $F_{i,1}$ | 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:



With (2019) Oxford Univ. Press.

(Lefkovitch) Transition matrix:

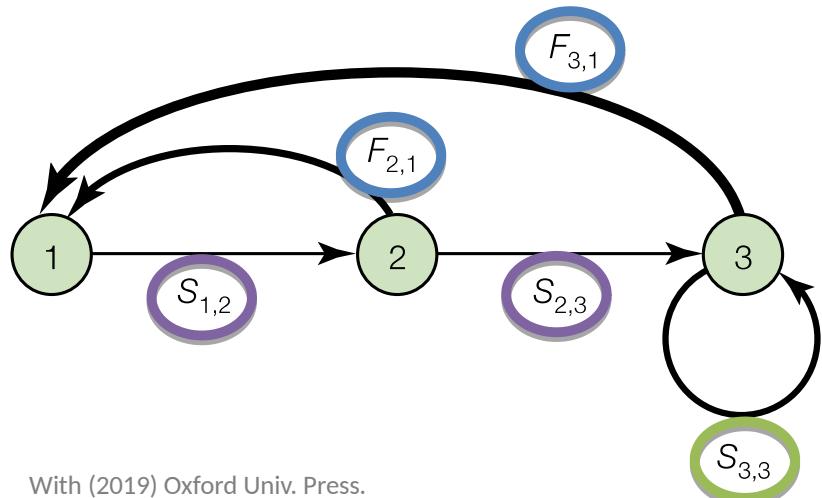
$$A = \begin{pmatrix} S_{1,1} & F_{2,1} & F_{3,1} \\ S_{1,2} & S_{2,2} & 0 \\ 0 & S_{2,3} & S_{3,3} \end{pmatrix}$$

The equation shows the Lefkovitch transition matrix A as a 3x3 matrix. The columns are labeled "Fecundity" (blue), "Development" (purple), and "Survival" (green). The matrix elements are: $S_{1,1}$, $F_{2,1}$, $F_{3,1}$ in the first row; $S_{1,2}$, $S_{2,2}$, 0 in the second row; and 0, $S_{2,3}$, $S_{3,3}$ in the third row.

RangeShiftR – local population dynamics

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Life-cycle graph:



With (2019) Oxford Univ. Press.

Lynx transition matrix:

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

RangeShiftR – local population dynamics

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

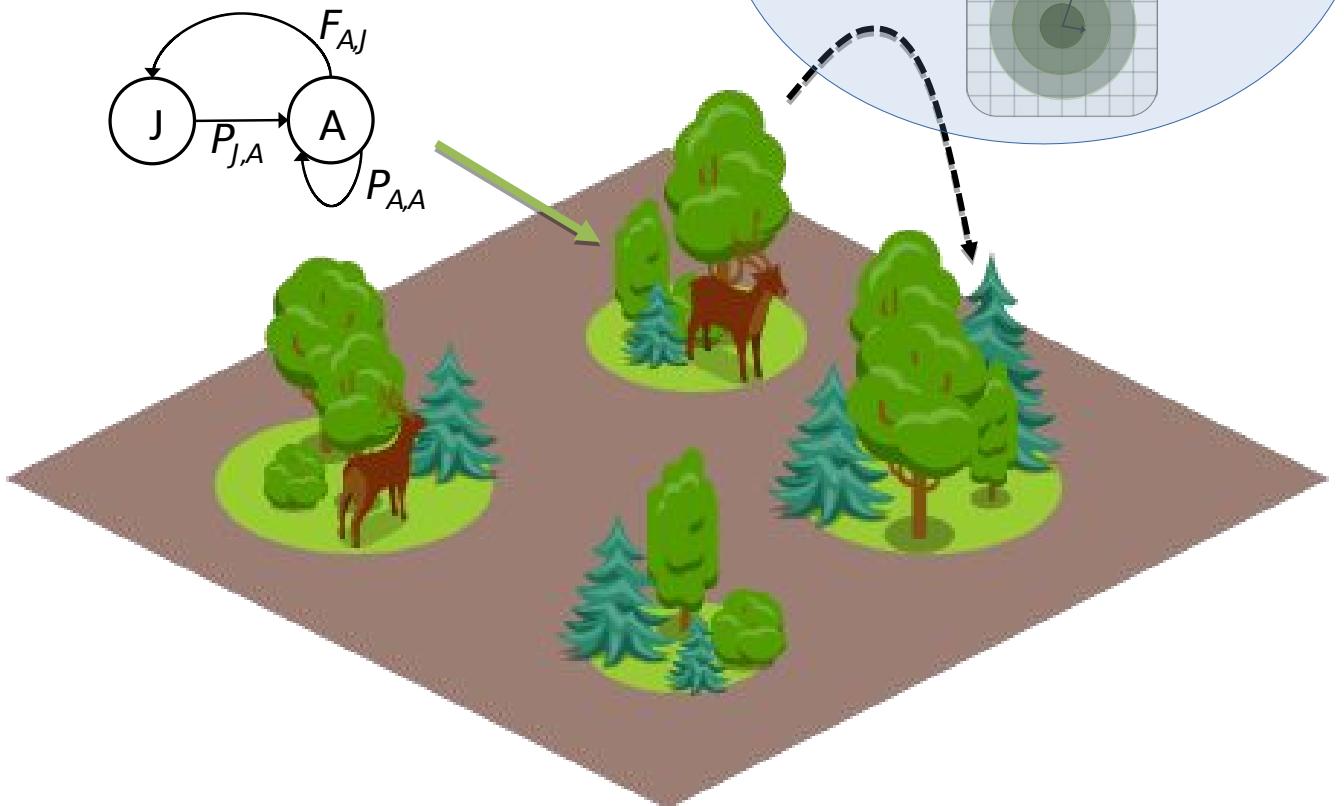
RangeShiftR – local population dynamics

- In RangeShifter, the processes of reproduction and survival / development happen subsequently
 - introduce “**stage 0**”
(for individuals that develop to stage 1 in the same year they are born)

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

Spatially explicit population models

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Dispersal described by
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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

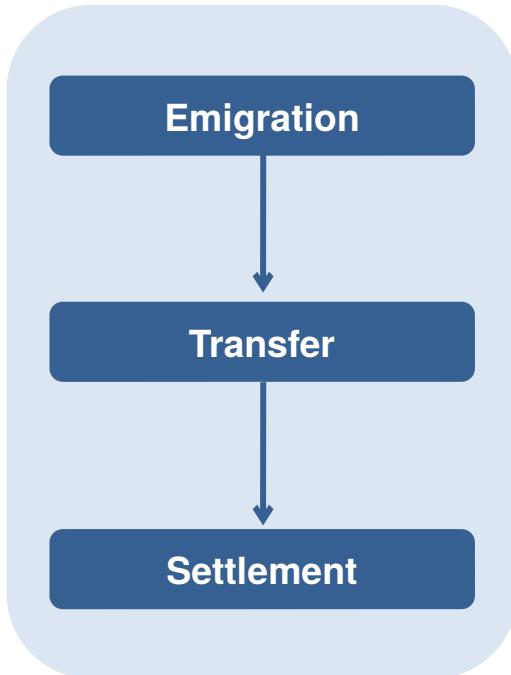
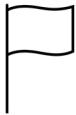
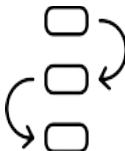
Dispersing individuals are a non-random subset of the population



(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.

RangeShiftR: three phases of dispersal

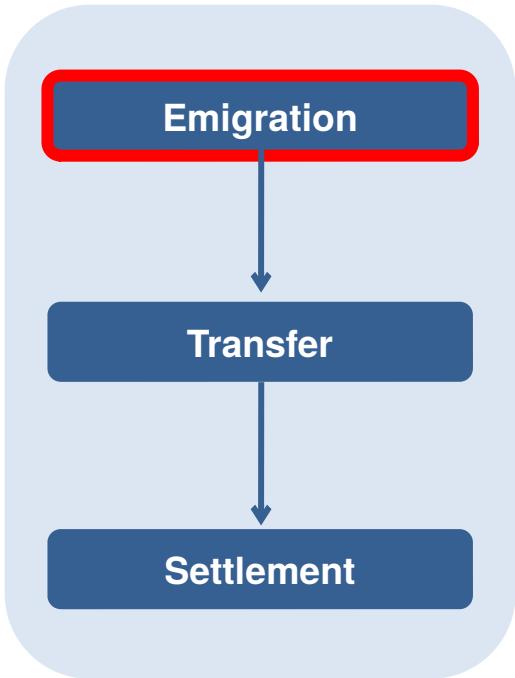


Leaving the natal site (area where born)

Movement through the landscape

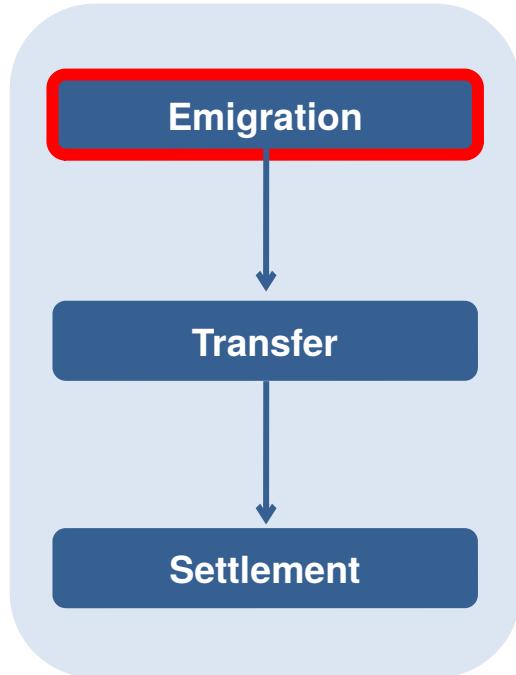
Establish in a new habitat site /area

RangeShiftR: three phases of dispersal



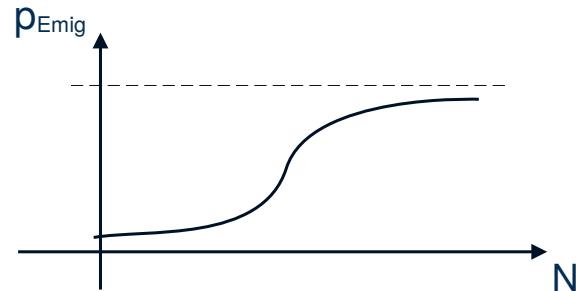
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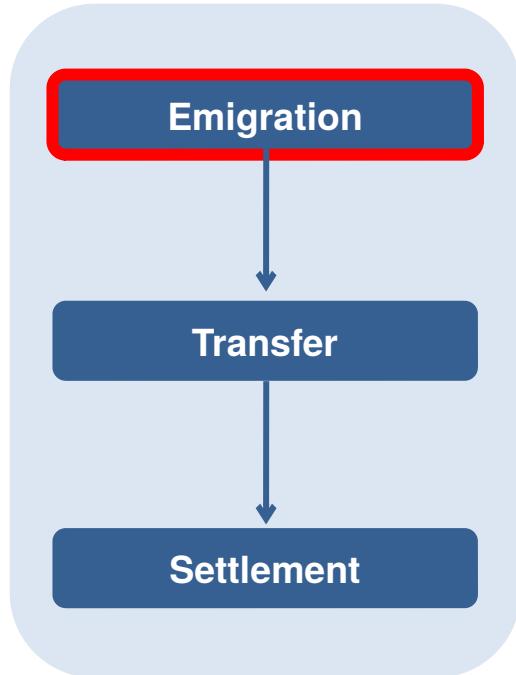


Emigration probability:

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

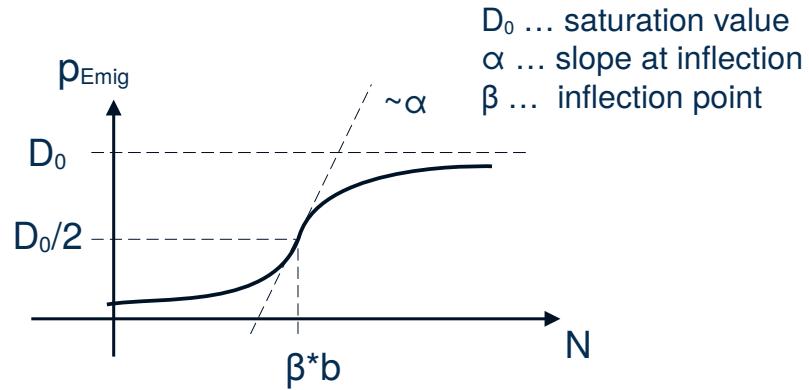


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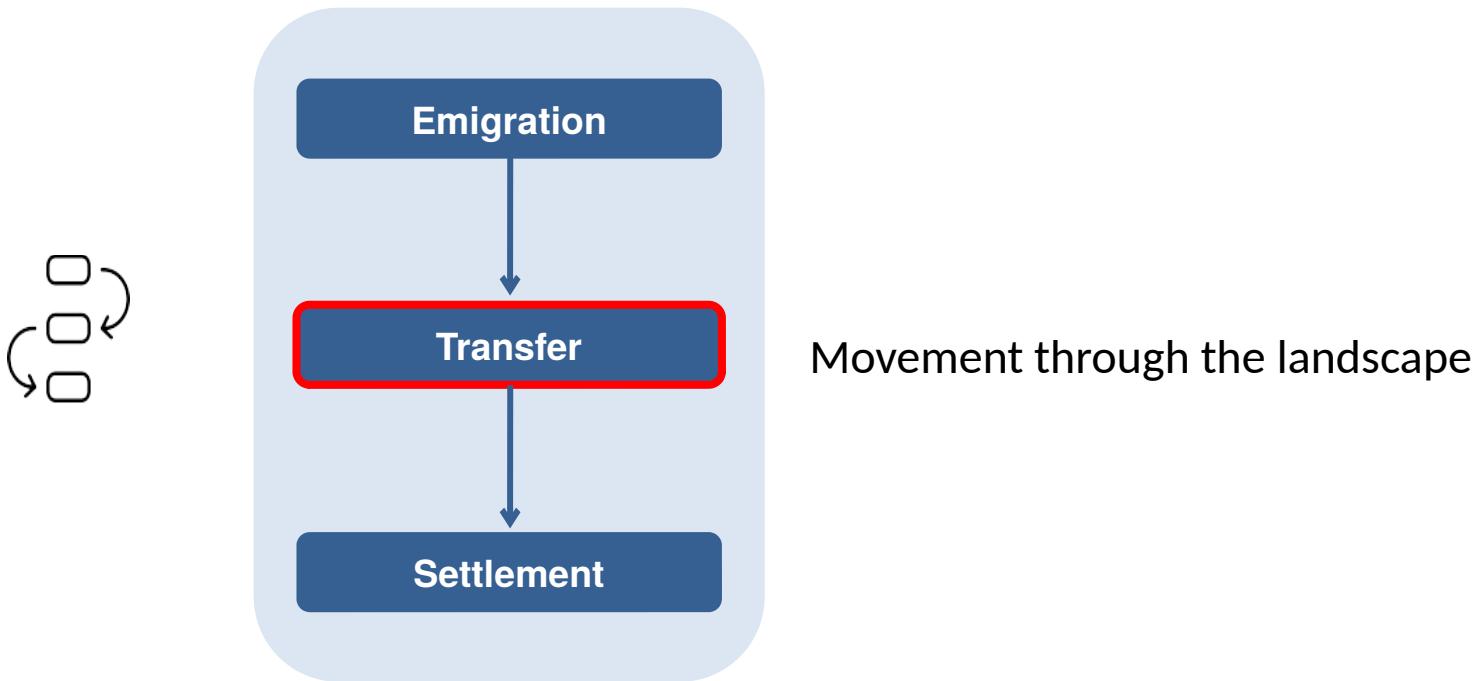
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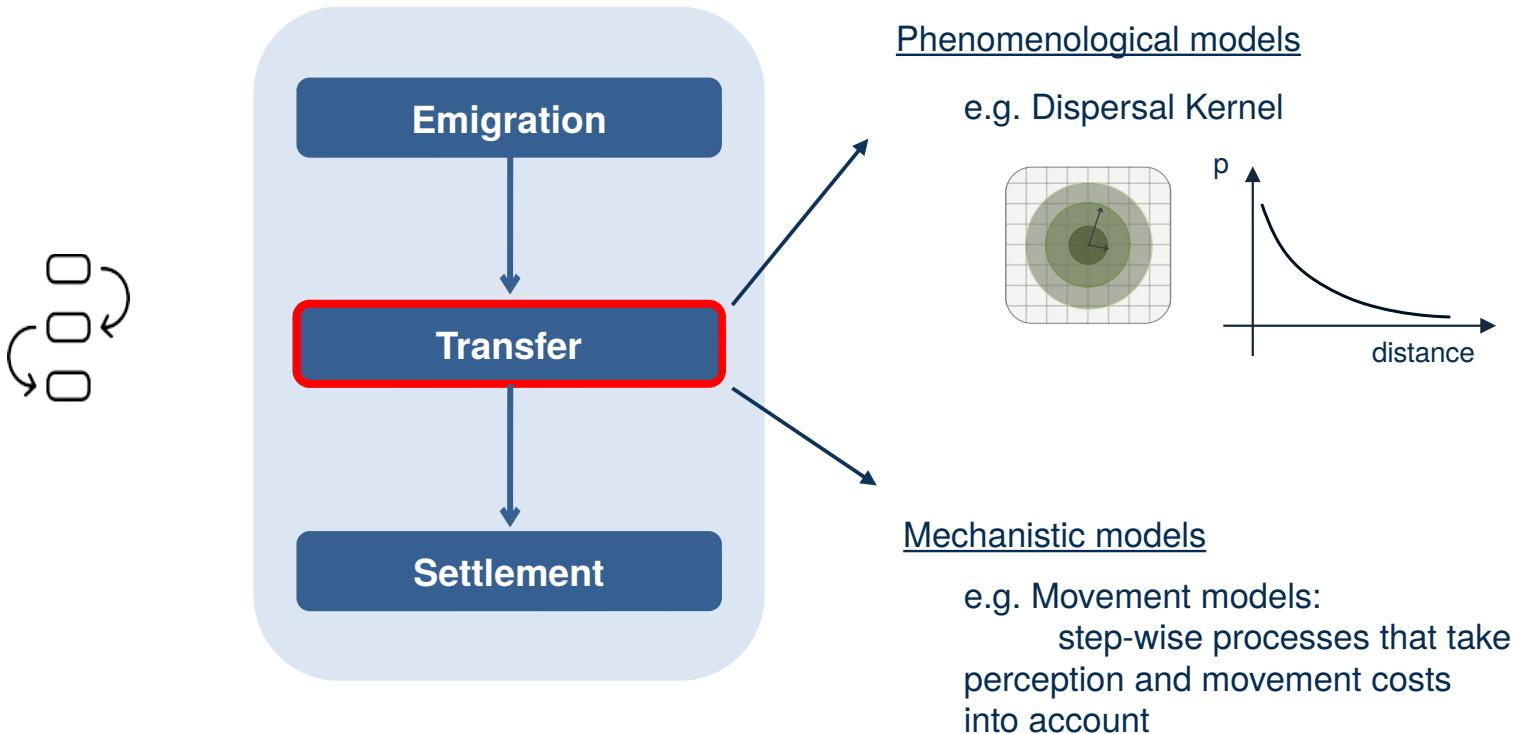
stage	sex	D_0	α	β
0	0	0.4	10	1
0	1	0.9	10	1
...

sex = 0 ... female
sex = 1 ... male

RangeShiftR: three phases of dispersal



RangeShiftR: three phases of dispersal



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

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

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Habitat cell



Current cell



Matrix cell



Perceptual area

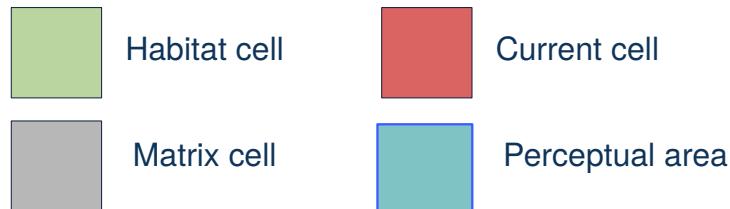
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- decision of next direction based on:
 - lowest average cost
 - preceding steps in memory (e.g. 3 steps)
 - directional persistence

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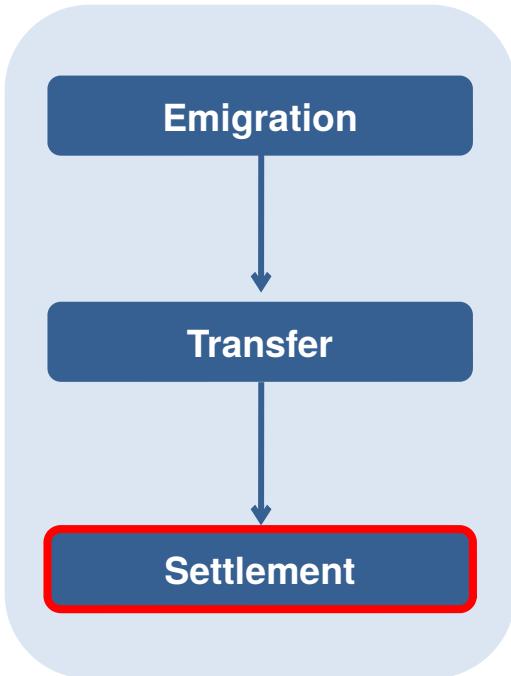


Matrix cell



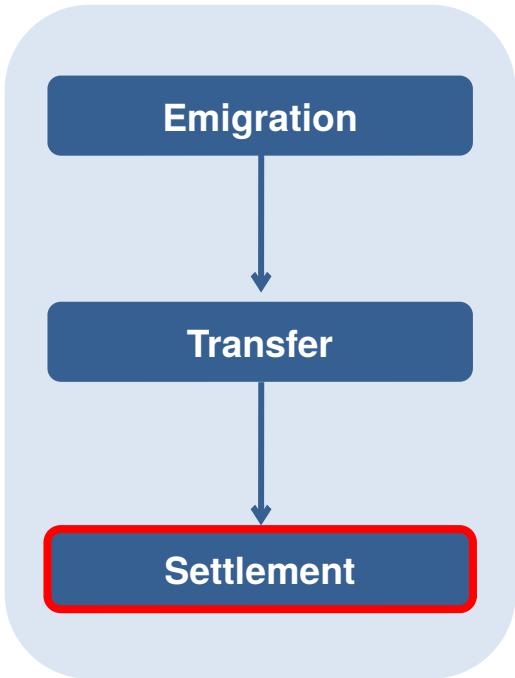
Perceptual area

RangeShiftR: three phases of dispersal



Establish in a new habitat site /area

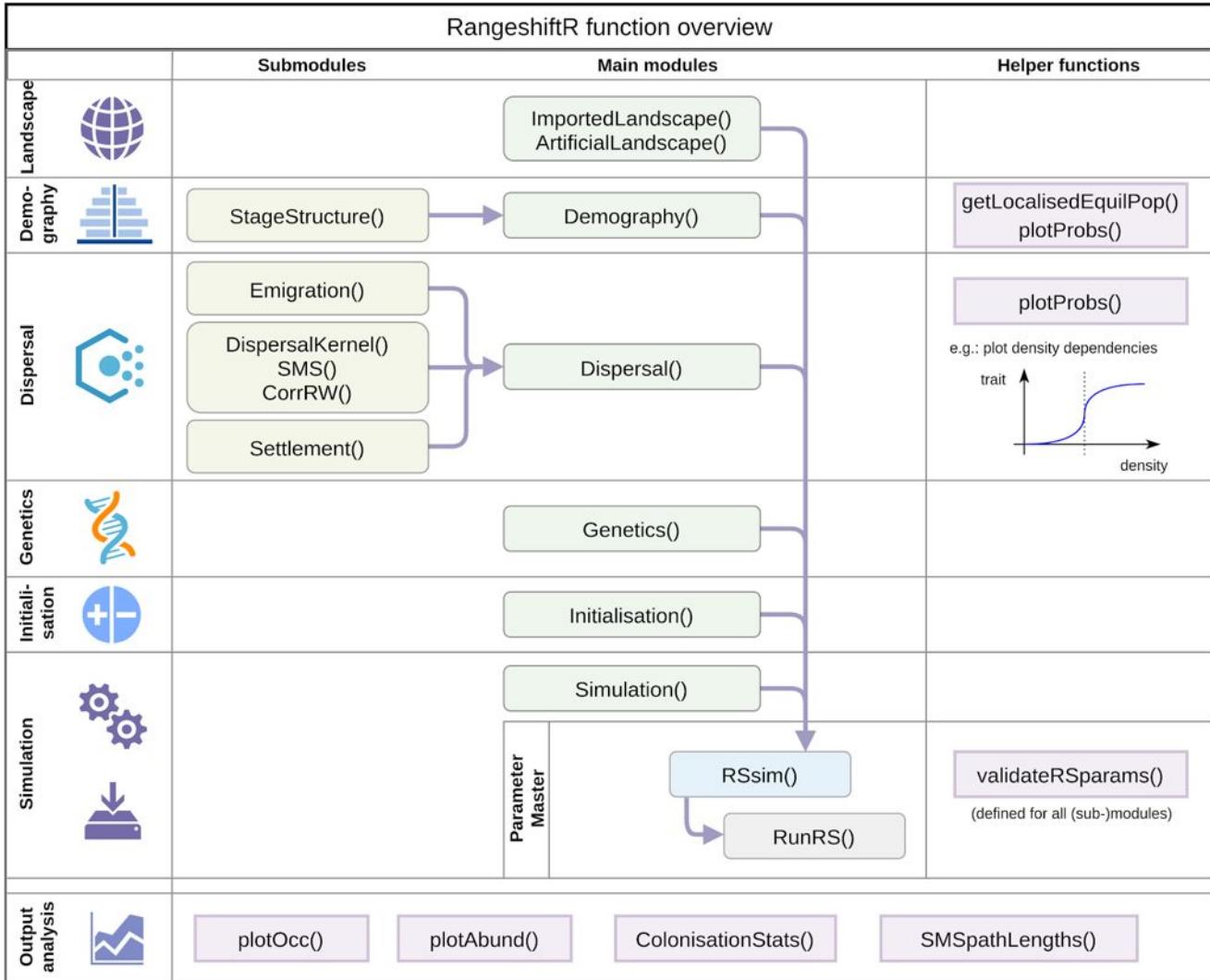
RangeShiftR: three phases of dispersal



Settlement probability:

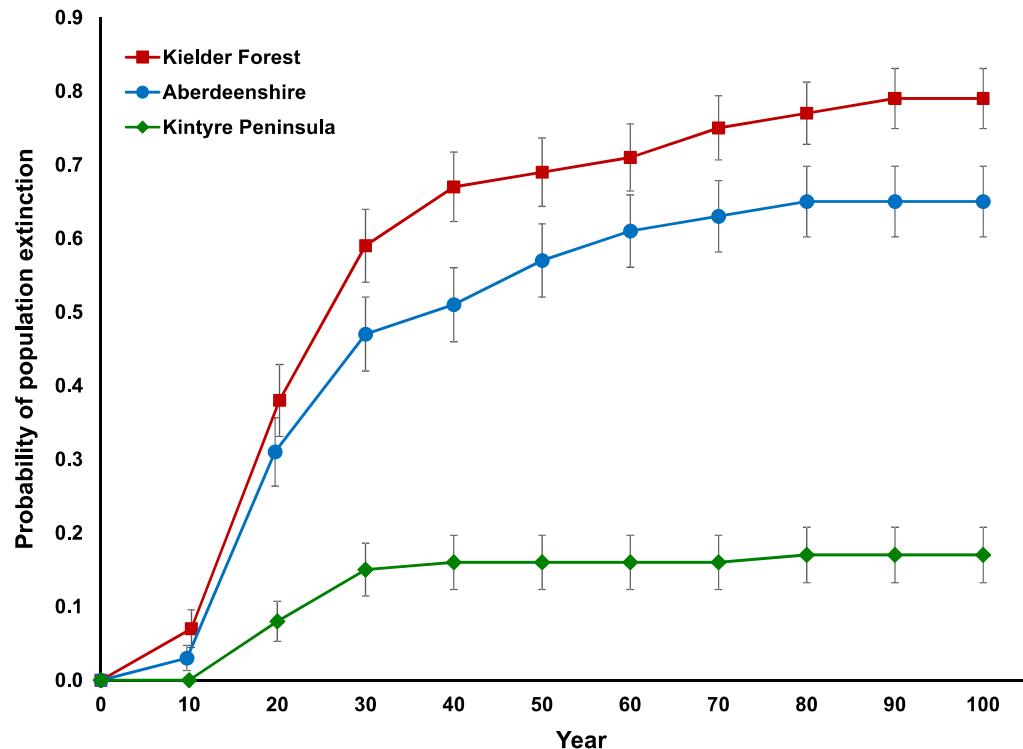
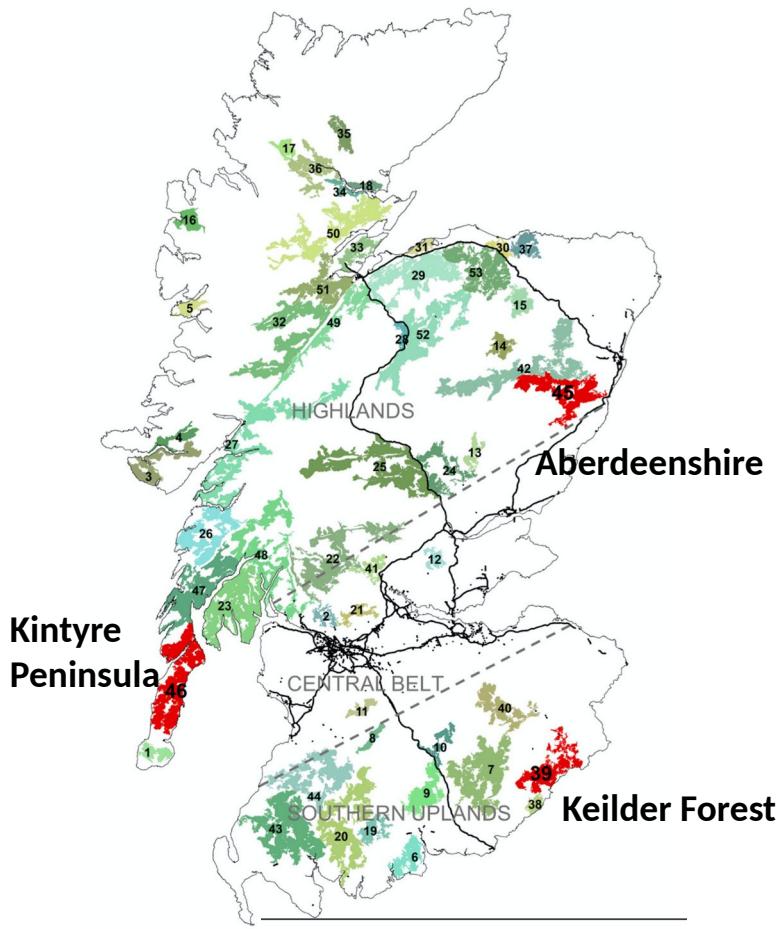
- the probability that an individual will stay in a new habitat patch
- can be density-dependent (analogous to emigration probability)

RangeShiftR overview



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

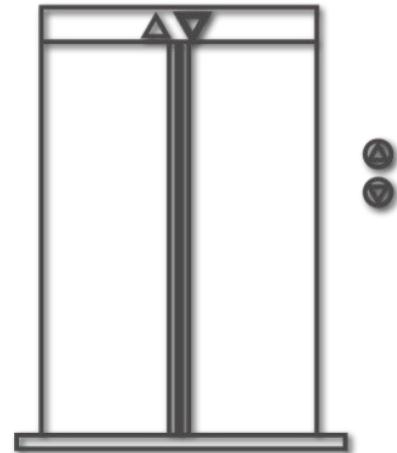


Break: 15 mins

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:

UNIVERSITY OF ABERDEEN

Greta Boocedi
Steve Palmer
Justin Travis

Anne Malchow
Damaris Zurell

Our Website:

<https://rangeshifter.github.io>



RangeShifter 2



RangeShiftR