Deterministic Individual-Based Cellular Automata Modelling of Single Species Population Dynamics

preprint

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Motivation

This presentation was created to characterise foundations of cellular automata modelling of single species population dynamics. Our method is deterministic, individual-based and is based on logical "*if-then*" statements only. As this method is bottom-up mechanistic and provides a direct visual insight into dynamics of complex systems, we used it to study mechanisms of interspecific competition in further experiments.

Basic provisions of the model

- The entire cellular automaton simulates a whole ecosystem;
- The lattice of the cellular automaton simulates a habitat;
- A single lattice site simulates a one microhabitat;
- A neighbourhood simulates a minihabitat;
- A one microhabitat may contain resources for life of a one individual.

States of a microhabitat

Each microhabitat (i.e. each lattice site) may be in one of three states:

- **Free**

(may be occupied);

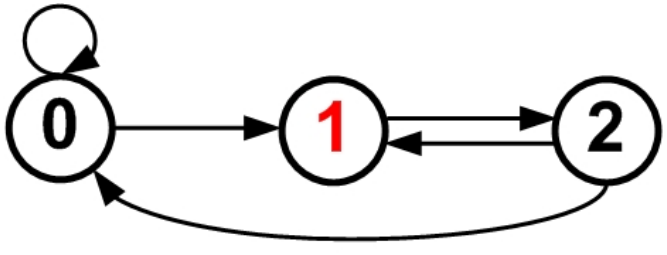
- **Occupied** by a one immobile individual;

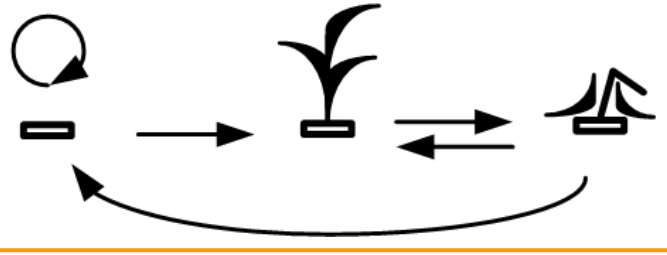
- **Regeneration**

(restoring conditions and resources of a microhabitat after an individuals's death and recycling of a dead individual).

Characteristics of the model

- The lattice consists of NxN sites and is closed to a torus.
- The set of states of a lattice site is {0, 1, 2}.
- The graph of the transitions between the states of a site (birth-death-regeneration process).





Properties of states of a microhabitat

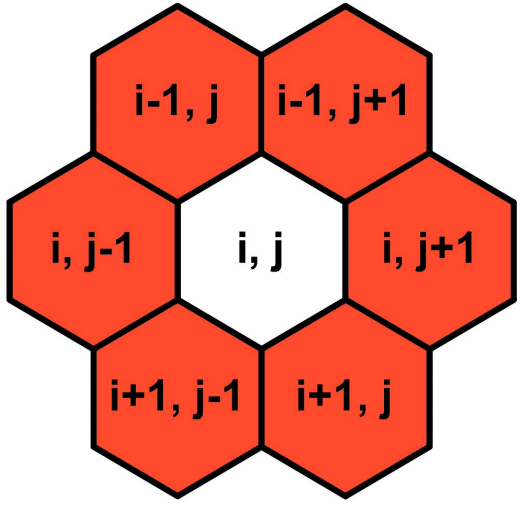
- A free microhabitat may be occupied only by one individual;
- Populated microhabitat and microhabitat in the regeneration state can not be occupied;
- Occupied microhabitat goes into the regeneration state after an individual's death;
- Microhabitat in the regeneration state becomes free or may be occupied after finishing of the regeneration state.

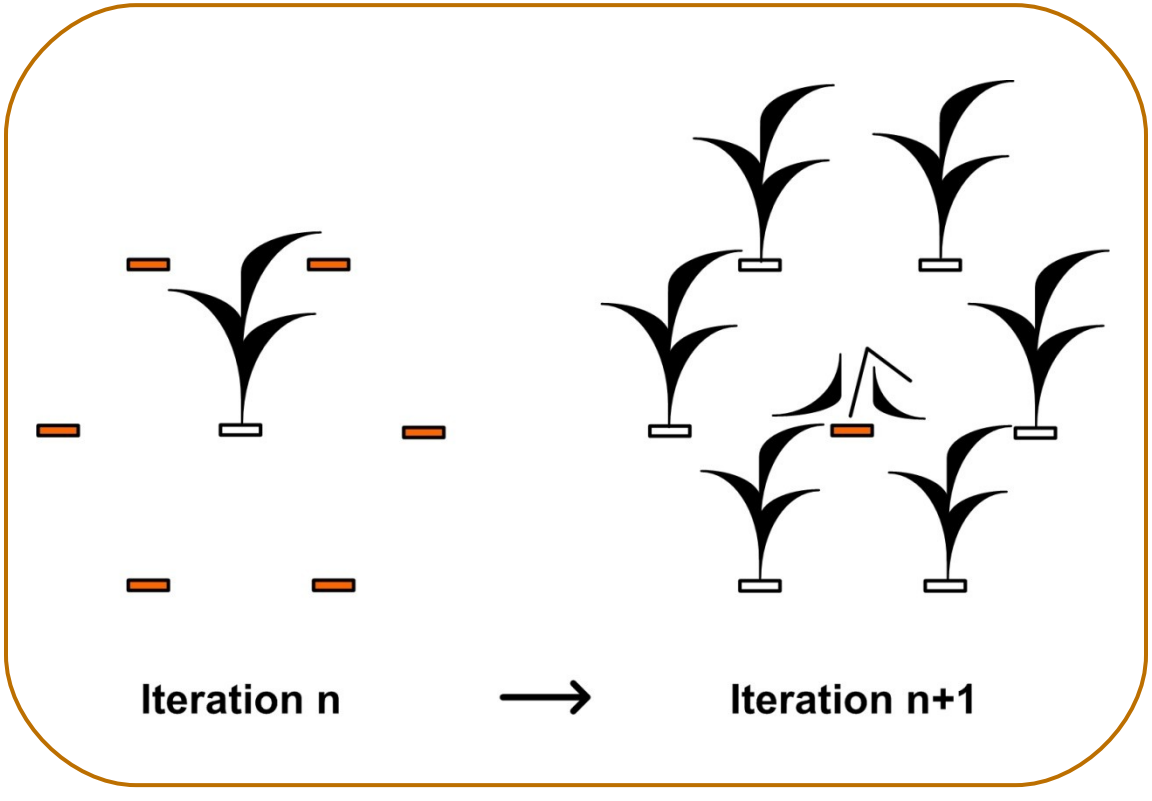
Neighbourhood

- A neighbourhood consists of a site and its intrinsically defined neighbour sites.
- All sites have the same rules for updating.
- A neighbourhood simulates an individual's minihabitat.
- A neighbourhood also determines the number of possible offsprings.

The closest analogy of an individual’s propagation determining by a neigbourhood is asexual (vegetative) propagation of turf grasses by rhizomes.

The hexagonal neighbourhood

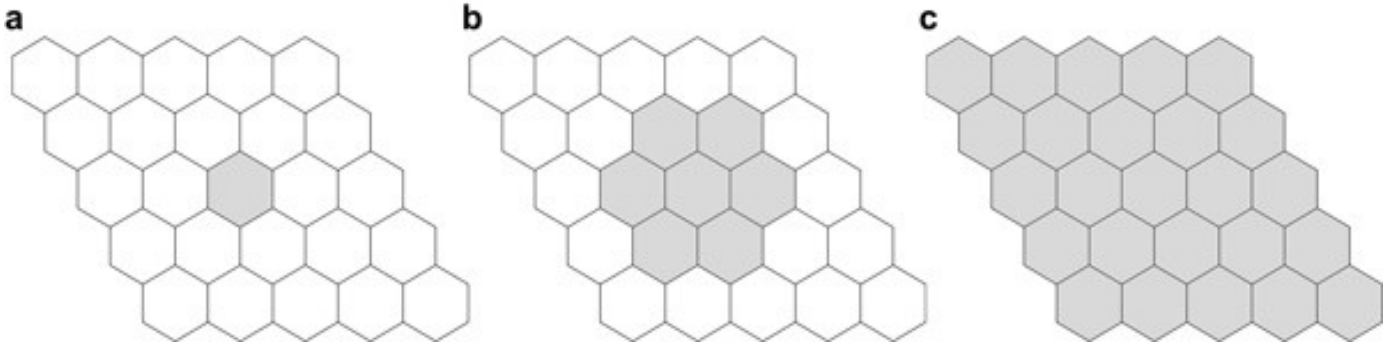




Vegetative propagation
of the grass tiller

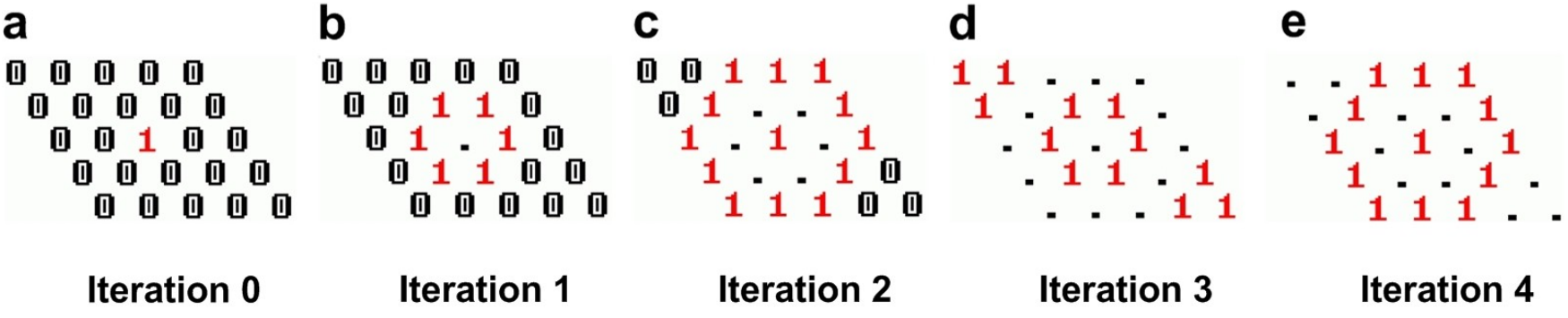
Microhabitat, minihabitat and macrohabitat.

Hexagonal neighbourhood on hexagonal lattice.

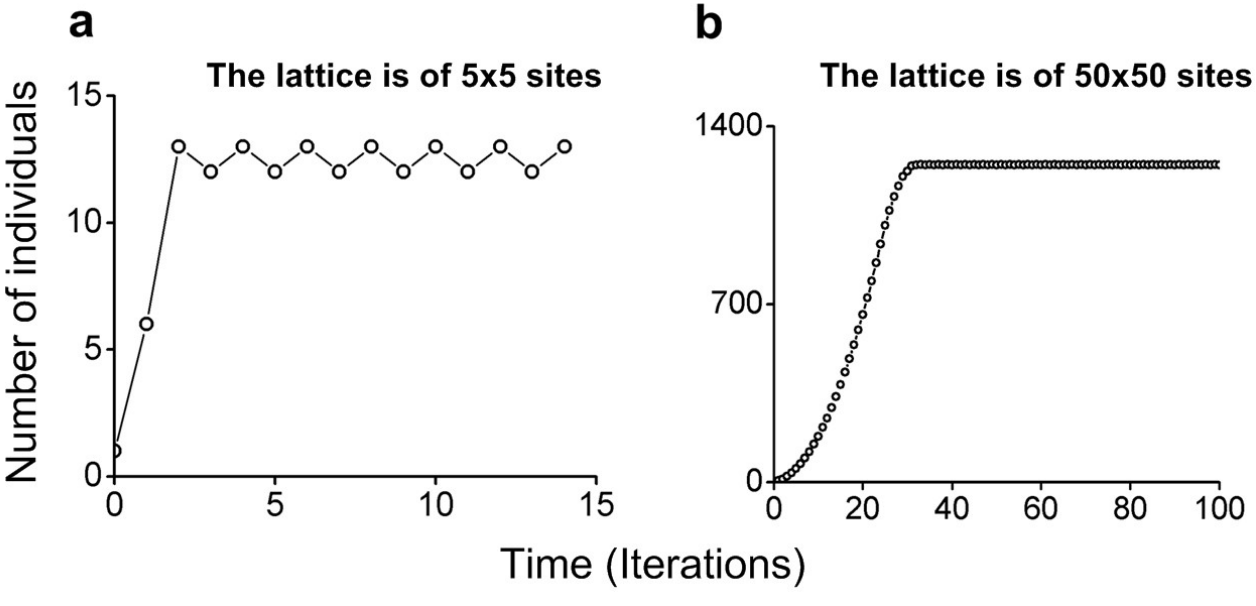


The grey colour indicates: **a**, Microhabitat (any one lattice site). **b**, Minihabitat (microhabitat and all the adjacent intrinsic neighbours). **c**, Macrohabitat (all field of the cellular automata). The lattice consists of 5x5 sites is used here as example.

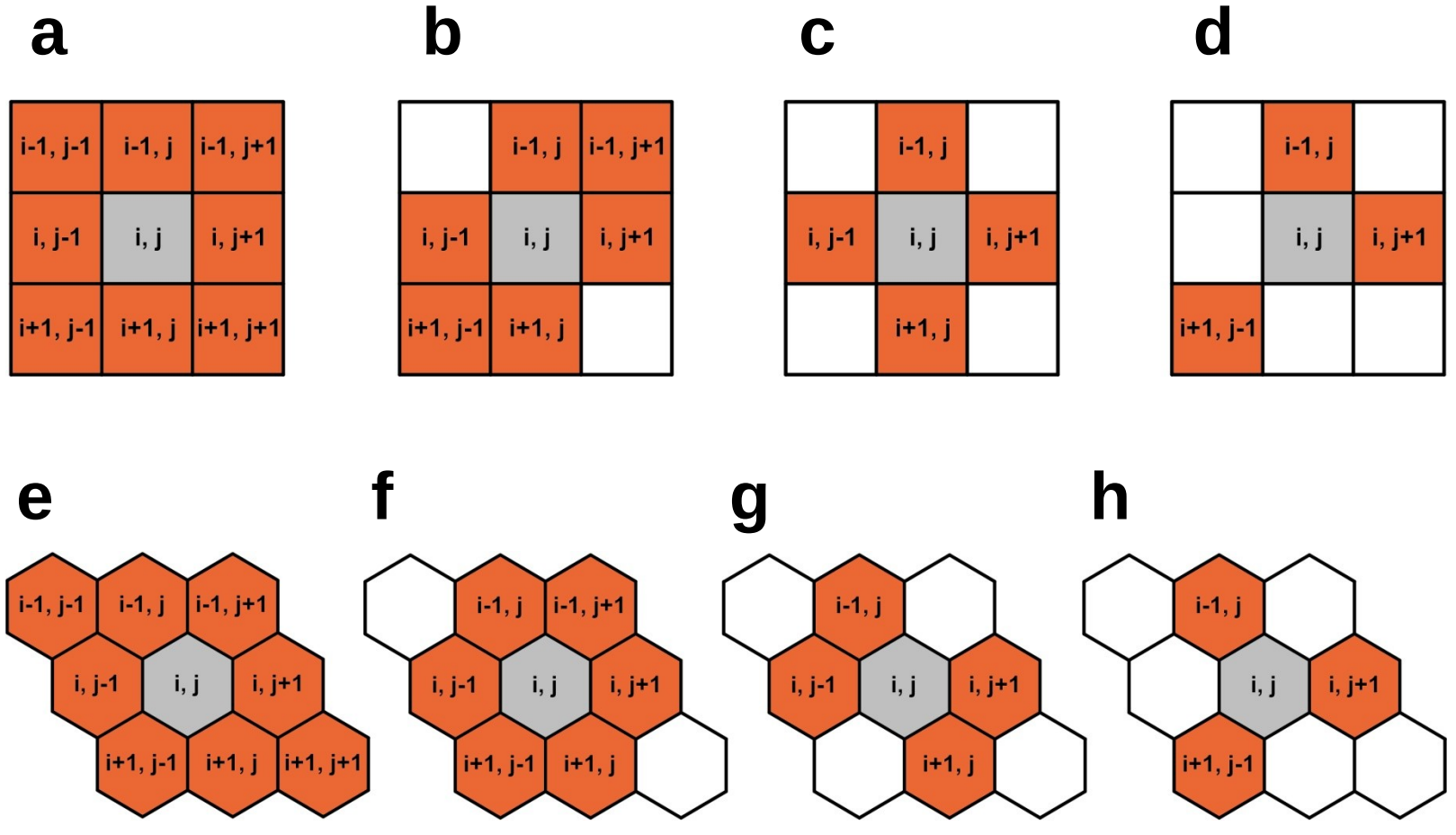
Modelling of population dynamics



‘0’ – a free site; ‘1’ – an individual of the species; ‘.’ – the regeneration state of a site after death of an individual of the species.



Various types of neighbourhoods



(**a**-**d**), the neighbourhoods on the square lattice - Moore, hexagonal, von Neumann and tripod. (**e**-**h**), the same neighbourhoods, but on the hexagonal lattice. i and j are integer variables.

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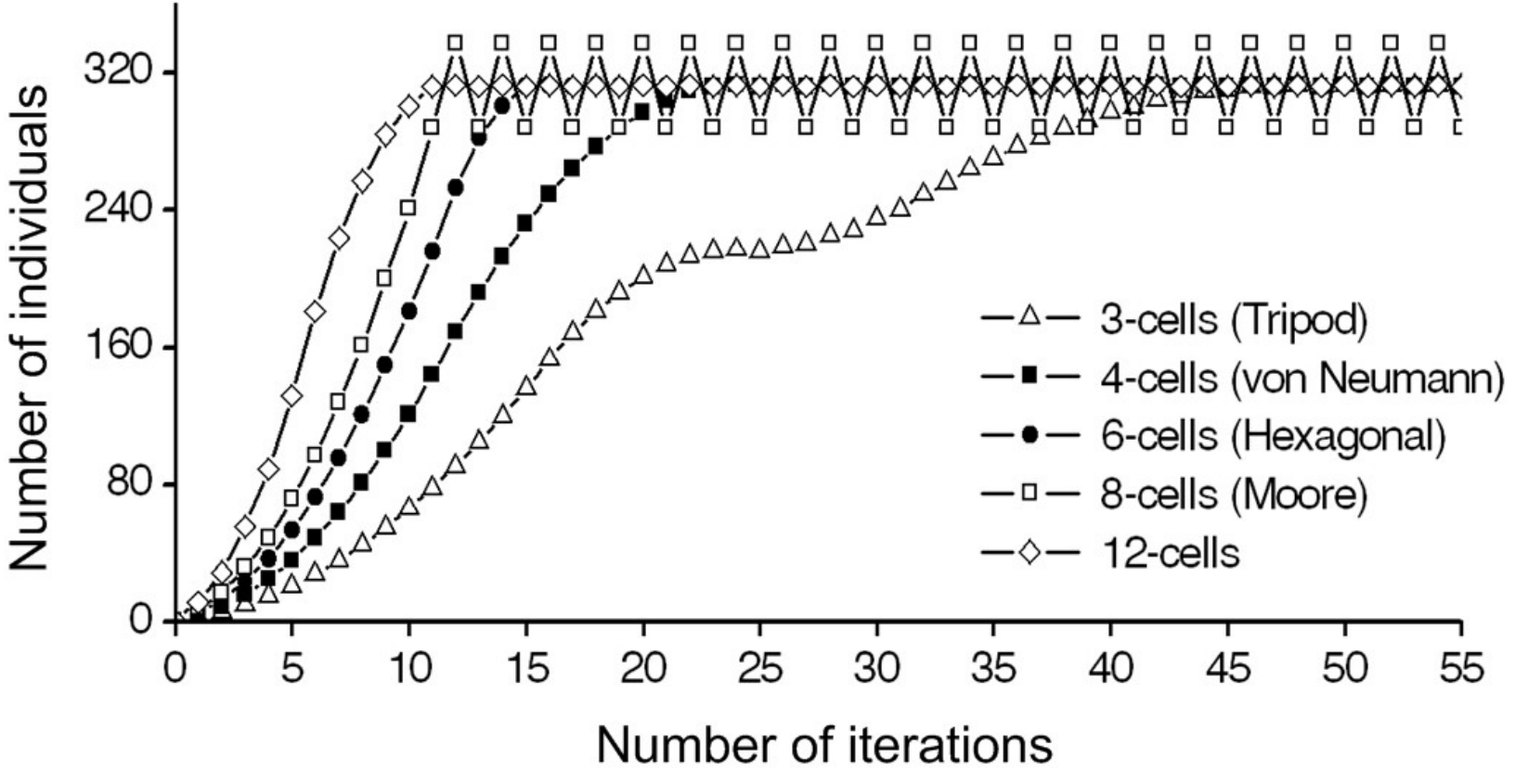
The relationship between fecundity rate and population growth rate

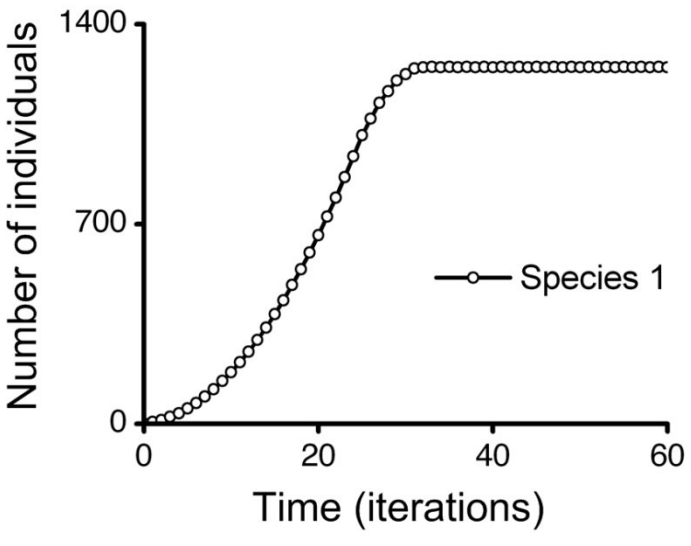


Fecundity rate (a possible number of offsprings per one individual) is determined by the type of the cellular automata neighbourhood. Hexagonal lattice is of 25x25 sites. One individual is placed on the lattice at the initial iteration.

Population growth curves

The lattice consists of 50x50 sites.

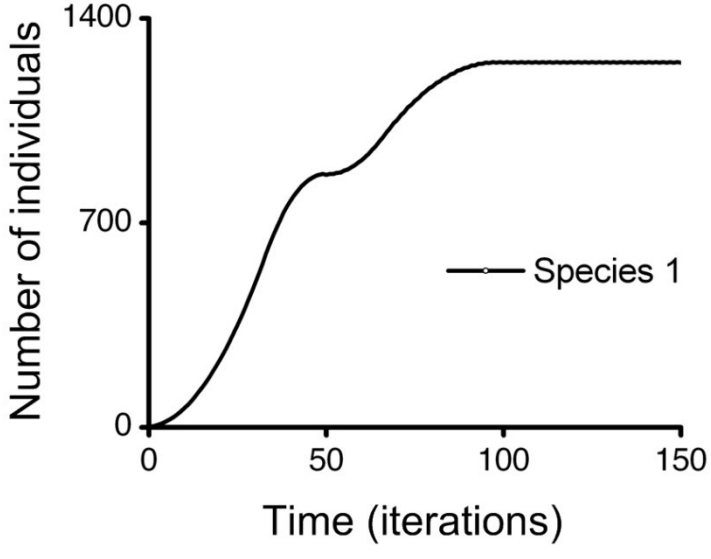
Hexagonal neighbourhood



Logistic-like curve

See movies S1 and S2

Tripod neighbourhood



Double logistic-like curve

See movies S3 and S4

Supplementary Movies

- S1. Single species population growth [7x7 Lattice; Hexagonal Neighbourhood]. Cellular automata.

  http://www.youtube.com/watch?v=3POc_IUpZ-k

- S2. Single species population growth [50x50 Lattice; Hexagonal Neighbourhood]. Cellular automata.

  http://www.youtube.com/watch?v=bkrh5vxcPt8

- S3. Single species population growth [7x7 Lattice; Tripod Neighbourhood]. Cellular automata.

  http://www.youtube.com/watch?v=AxLnJrlJ09E

- S4. Single species population growth [50x50 Lattice; Tripod Neighbourhood]. Cellular automata.

  http://www.youtube.com/watch?v=_hxh4iQrmhI

Author contributions: V.L.K. designed the research. L.V.K. created the programs, investigated the models and made figures and movies of the experiments. Both authors discussed the results, interpreted them and wrote the text.