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Using Flexible Time Scale to Explore the Validity of Agent-based Models of Ecosystem Dynamics

Application to Simulation of a Wild Rodent Population in a Changing Agricultural Landscape

Jean Le Fur and Moussa Sall

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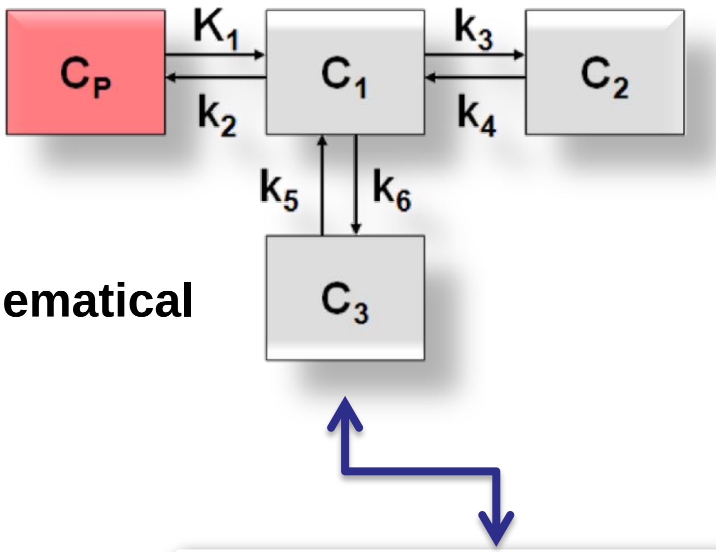
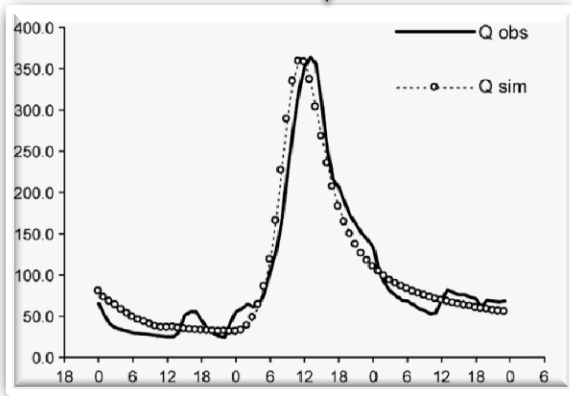
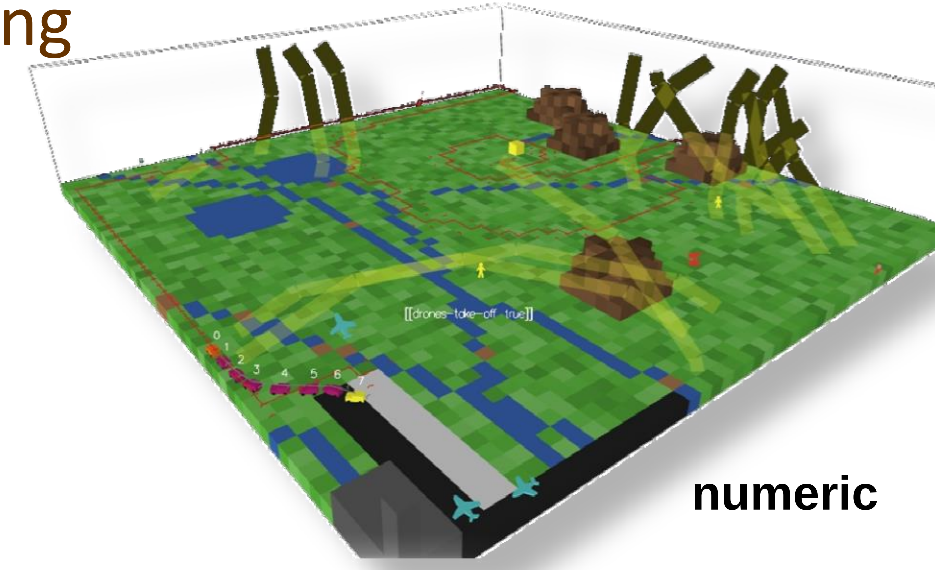
CBGP Centre de Biologie pour la Gestion des Populations
IRD Institut de Recherche pour le Développement FRANCE
Université Gaston Berger de Saint-Louis du Sénégal
CEA MITIC Centre d'Excellence Africain en Mathématiques, Informatique et TIC

CALIBRATION : Identifying models' parameters value is a major issue in model engineering



mathematical





numeric

physical

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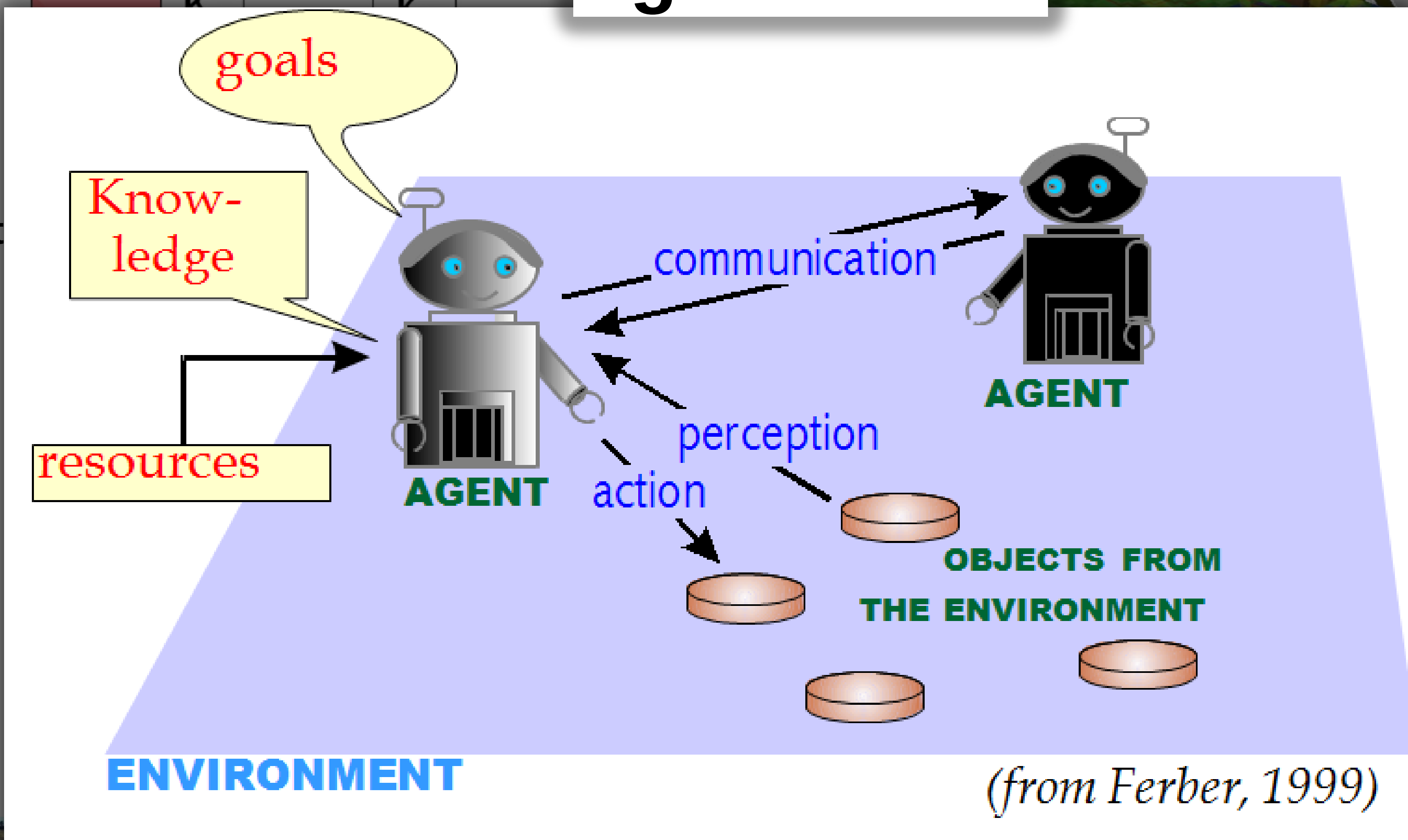
Identifying models' parameters value is a major issue in model engineering (cf. Watts, 2016)

Agent-based

mat



ic

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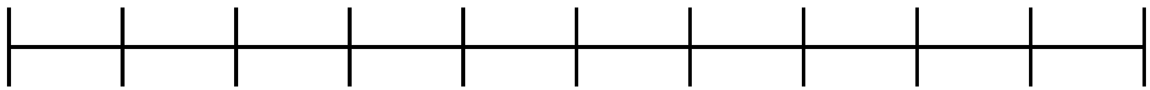
physical

Calibration in agent-based models

- Calibration question differs from one formalism to the other, from one use case to the other
  - *e.g.*, in agent-based models:
    - Discrete Time Simulations
    - Discrete Event Simulation

Discrete time simulations (DTS)

- Discrete time agents sequentially perform deliberation/actions once each time step



Process Simulation has uniform step sizes

- As a general use, DTS time step is fixed to one realistic value, given the use case, when other parameters may change.
- However, time step choice may have impact on models' outcomes
  (Buss and Roawei, 2010, Kuo, 2015)
  - it is often difficult, if possible, to **determine if one agent has to process the selected scheme once each second, two seconds, minute, hour, day or the like**

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Aim of the Study

- Configure a discrete time agent-based model of a rodent population
  - Model's target: perennial rodents' population (*i.e.,* long term lasting)
- Configure the model to be run at several time scales

➡ Design and conduct a sensitivity analysis of the model to time scale

- Evaluate the optimal time step duration

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Summary

- Introduction
- Use case overview
- Presentation of the model
  - Simulation Outputs
- Time scale sensitivity analysis
  - Time scale dependencies
  - Protocol selected
- Result
- Discussion

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Use case overview

Agent-Based Model of a Rodent Population in the Wild

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Presentation of the case study

France, Poitou-Charentes region

Landscape of plains and open fields
(spring, winter, alfalfa, grassland cereals)
in which rodents evolve

Question: use of agricultural land by rodents?

Common vole (Microtus arvalis)

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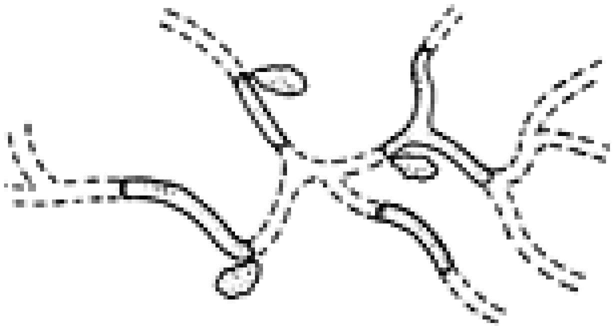
Burrow systems of voles colonies



APPROACH: Mechanistically rich agent-based modelling*(*)*

Observed dynamics come from the combination of various phenomena

Include: abiotic, trophic, physiological, behavioural, social, demographic and environmental mechanisms, landscape dynamics.
- each the most parsimonious way -

Outcome: formalize the dependency of each causal chains and produce global patterns.

Consequence: complex patterns that cannot be systematically interpreted but can be studied by modifying the model's logic or parameters.

(*) Uchmanski and Grimm, 1996, De Angelis and Mooij, 2003, Topping et al., 2010)

Model Presentation

- **Dynamic habitats**
- **Rodent agents**

- **Simulation outputs**

Le Fur, Mboup & Sall (Simultech 2017)
A Simulation Model for Integrating Multidisciplinary Knowledge in Natural Sciences

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Simplified representation of the habitats variety

Habitats encountered in the field :

hedges

meadows

fields

Houses and roads

motorway

(5)

(1)

(0)

simplification

(rodent affinity for the habitat)

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Simplified representation of the habitats variety

Habitats (rodent affinity for the habitat)

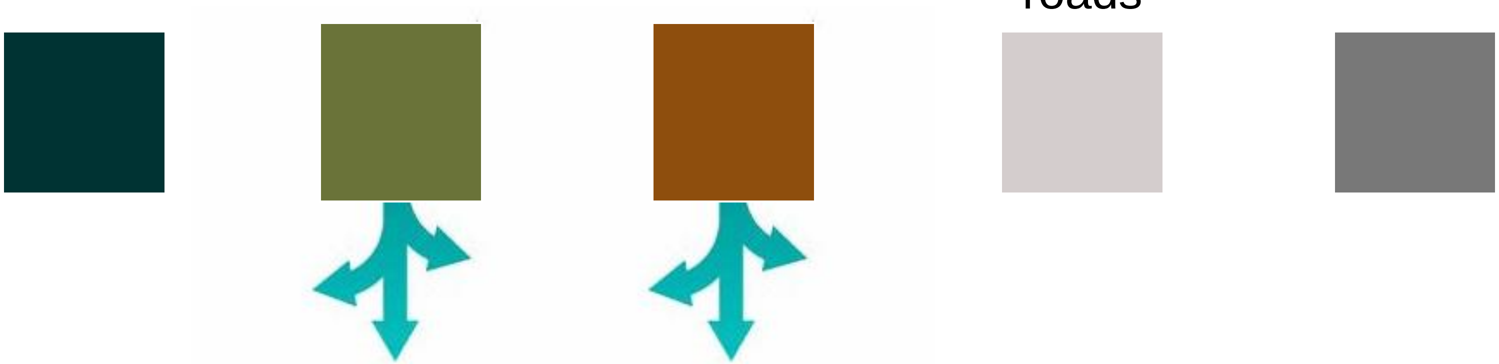
hedges

meadows

fields

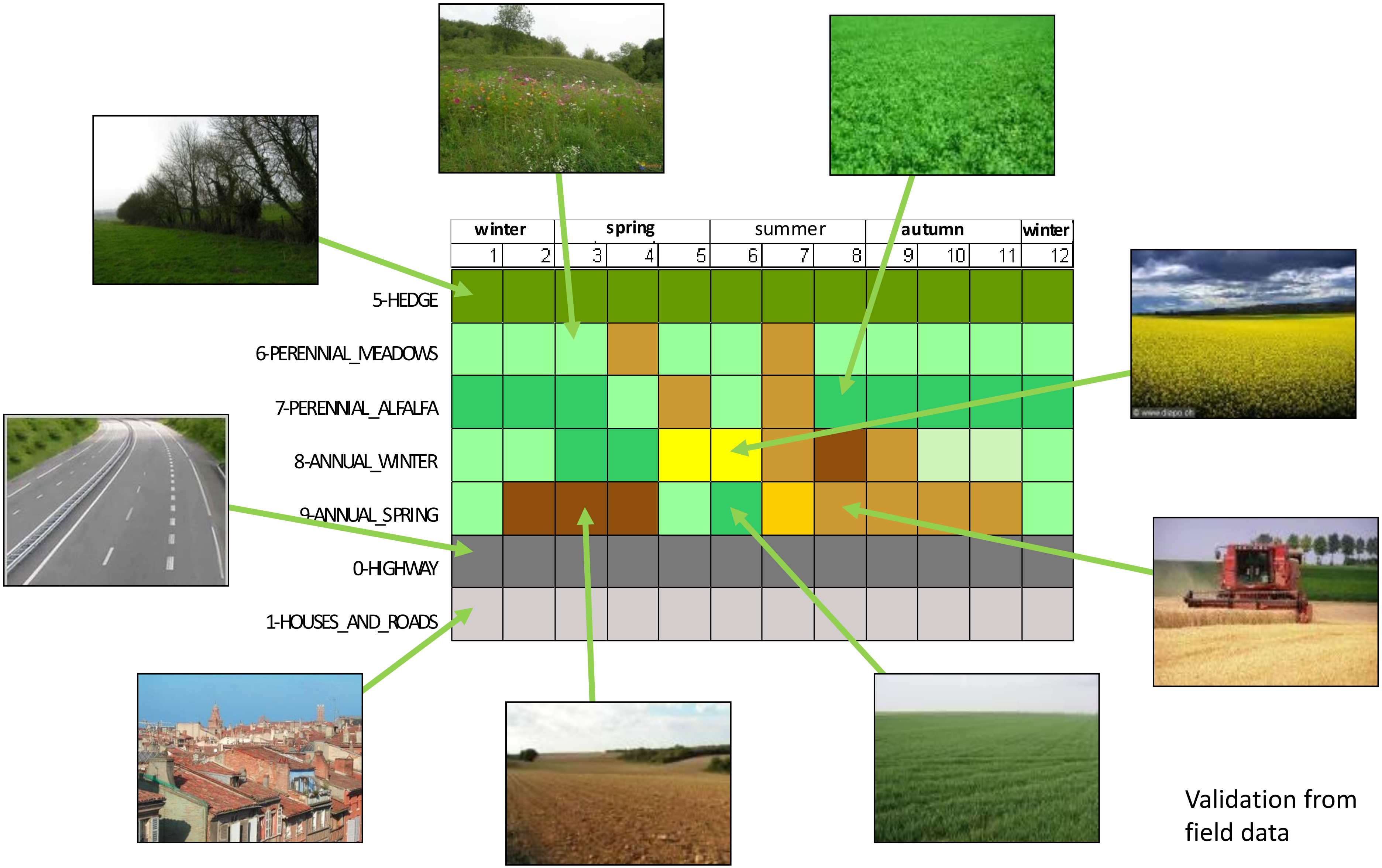
houses and roads

motorway



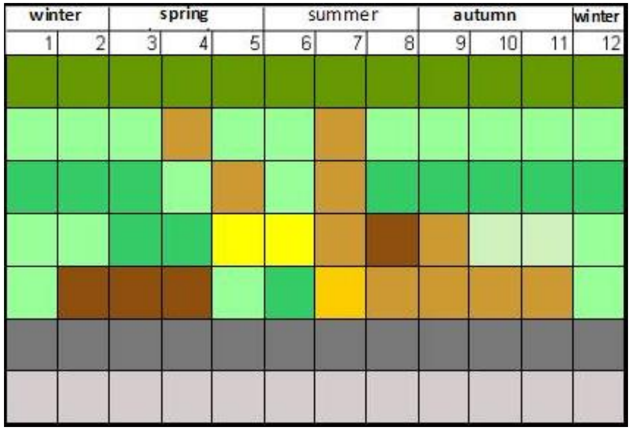
Technical operations

Technical operations (annual dynamics of the landscape)

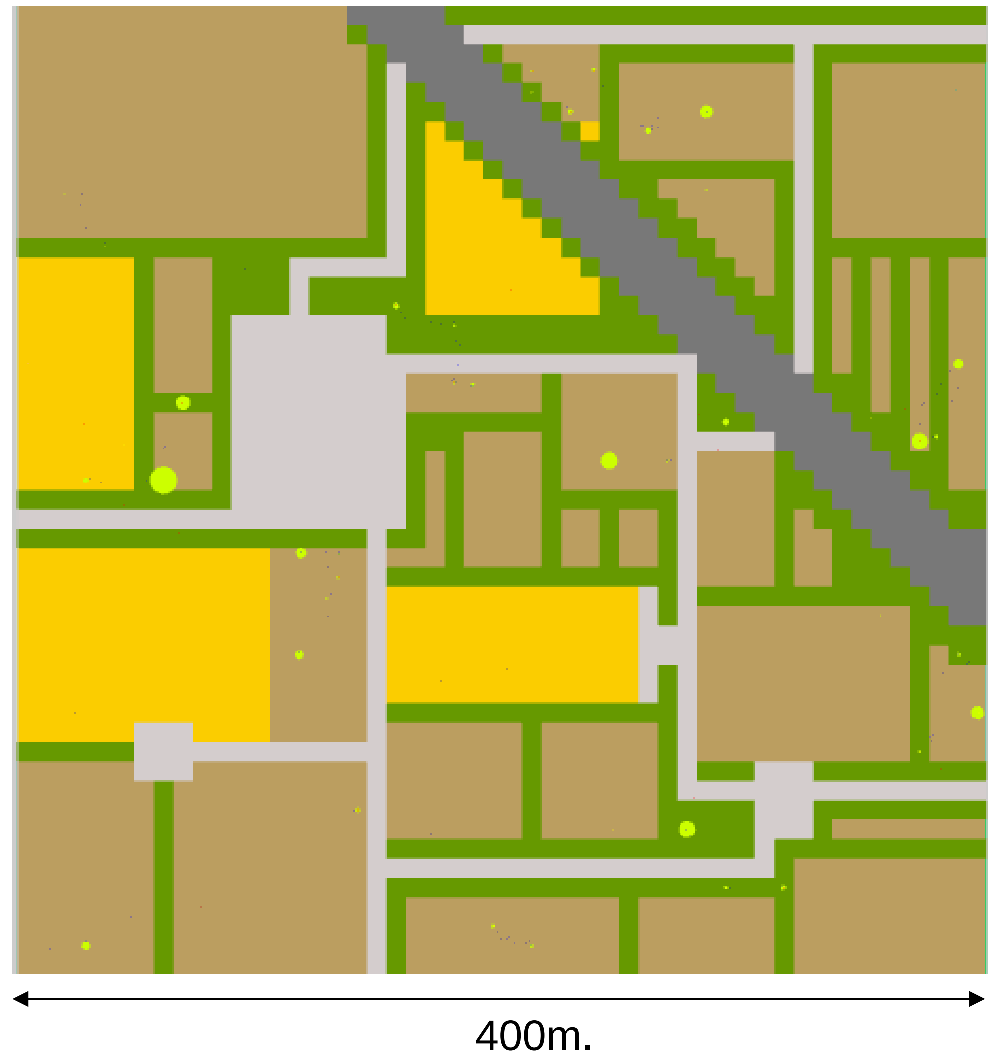


Validation from field data

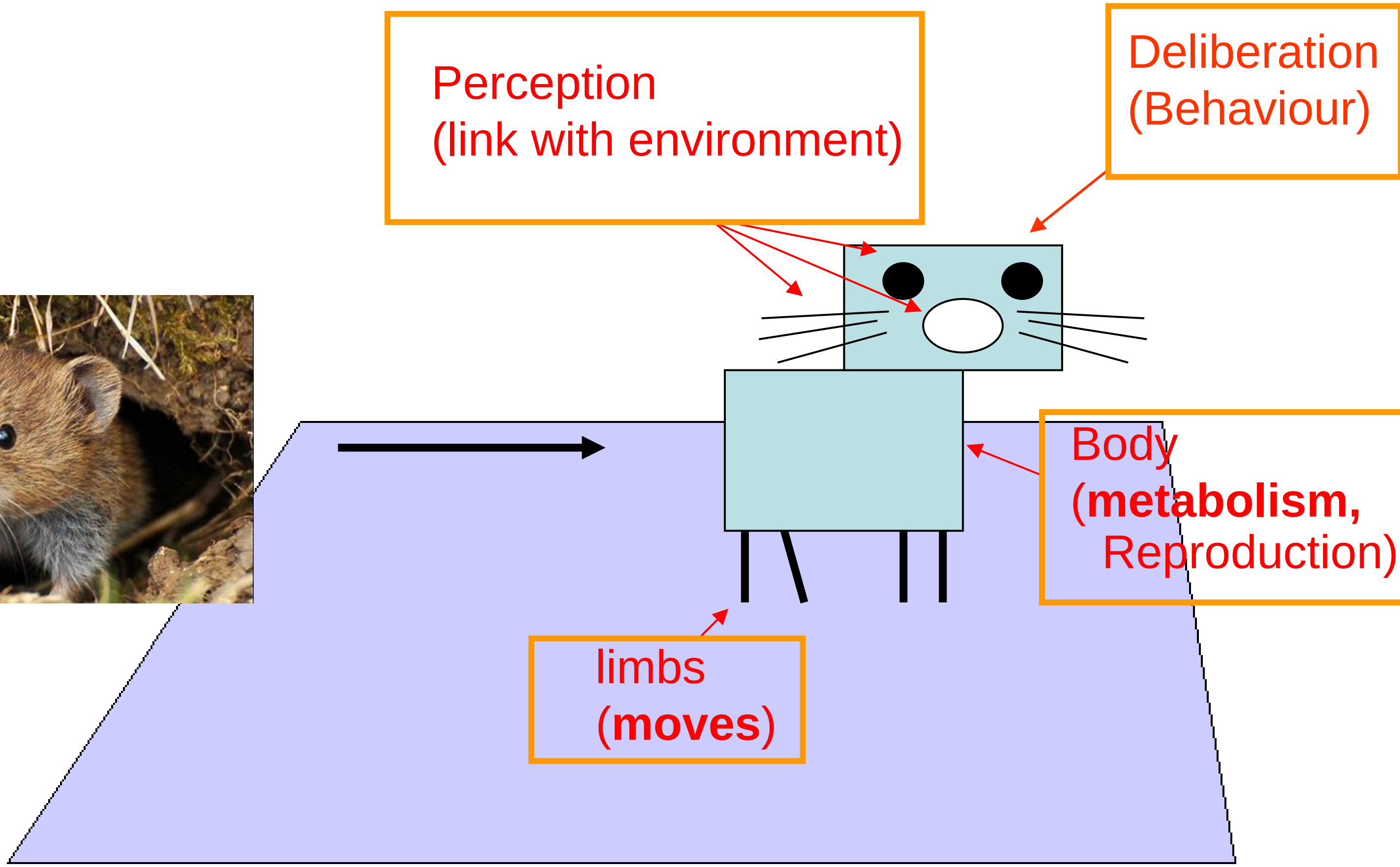
Resulting landscape dynamics on a theoretical grid



Crops change with seasons

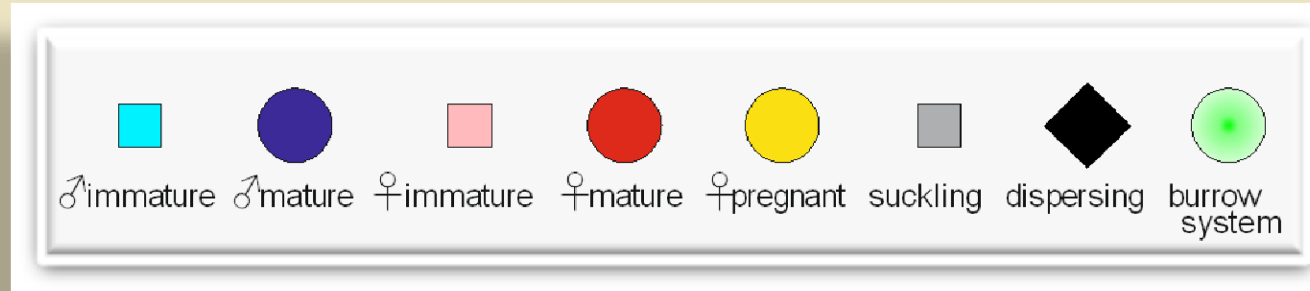


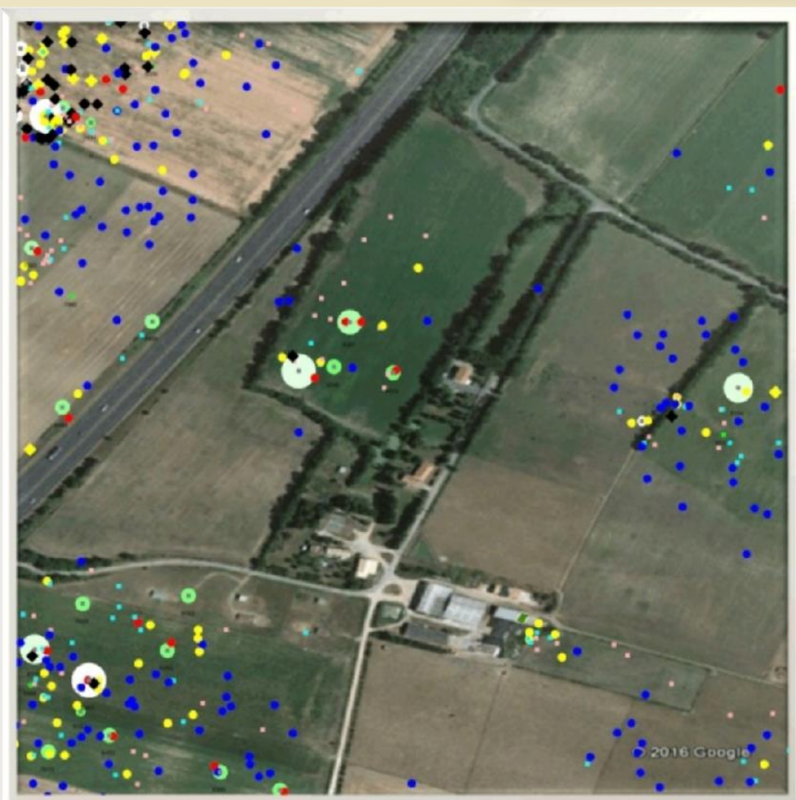
Rodent Agents Competencies

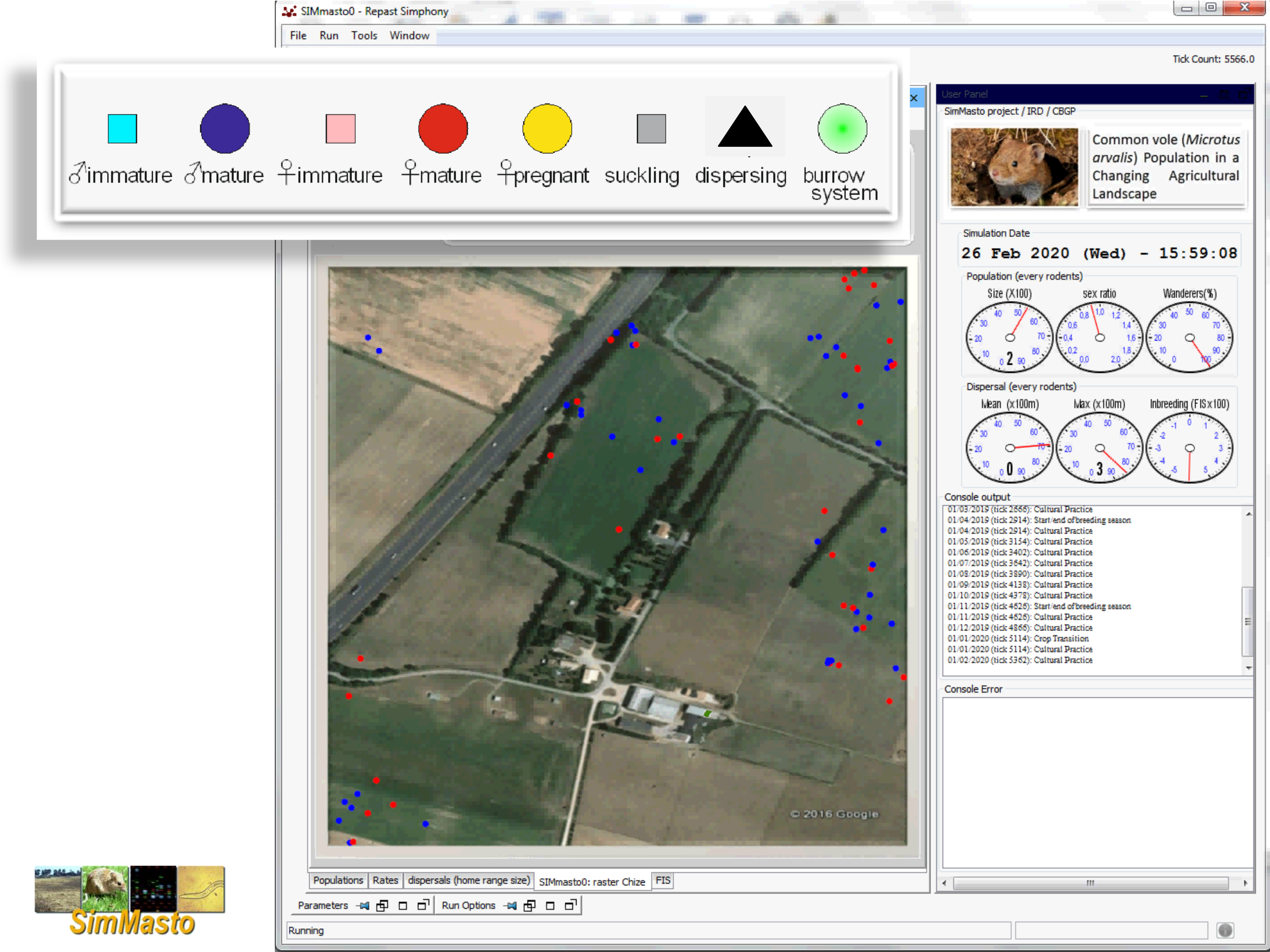


… within a changing landscape

Simulation outputs

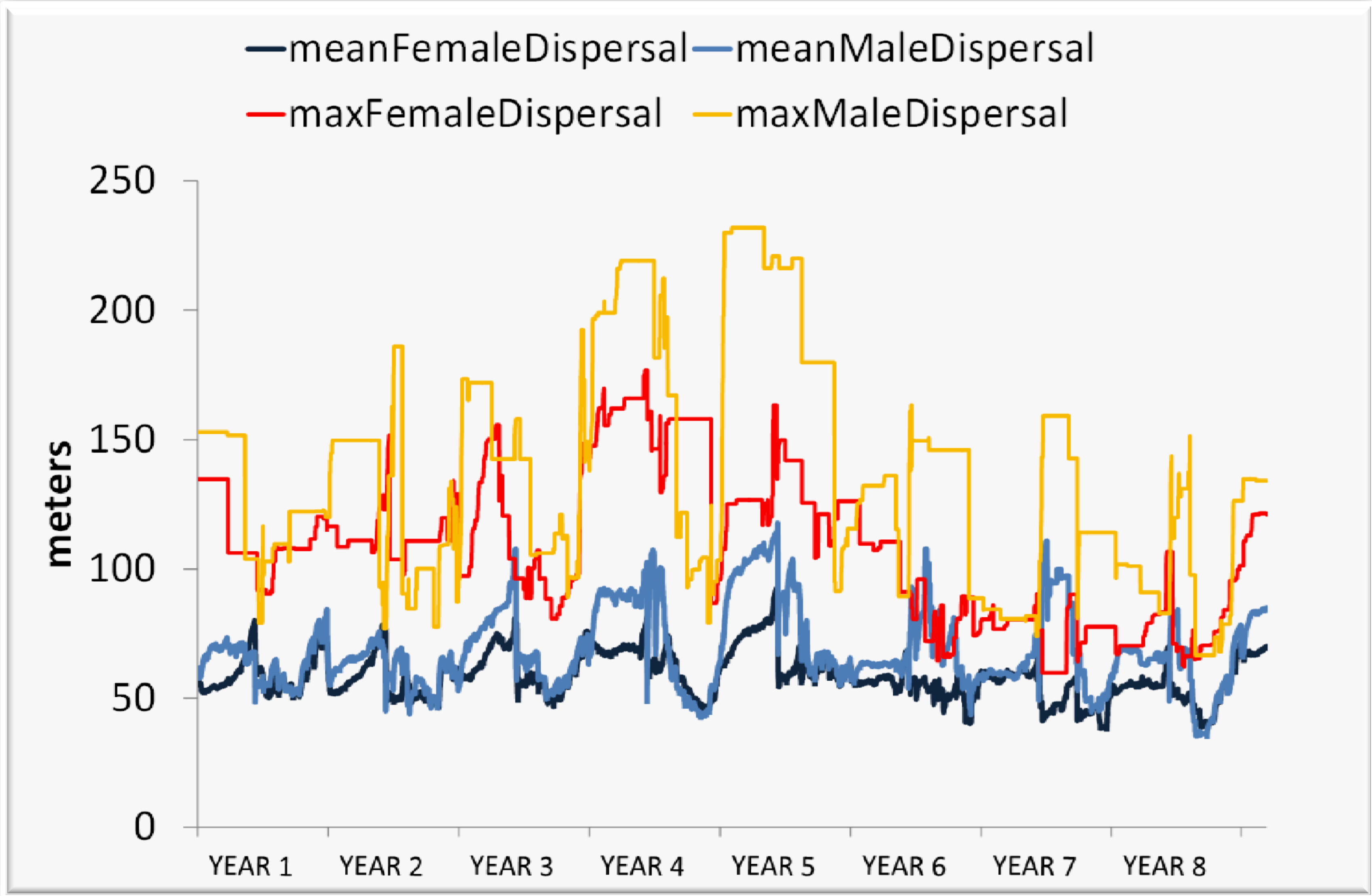






♂immature
♂mature
♀immature
♀mature
♀pregnant
suckling
dispersing
burrow system
SIMmasto0 - Repast Simphony
File Run Tools Window
Tick Count: 5566.0
User Panel
SimMasto project / IRD / CBGP
Common vole (*Microtus arvalis*) Population in a Changing Agricultural Landscape
Simulation Date
26 Feb 2020 (Wed) - 15:59:08
Population (every rodents)
Size (X100)
sex ratio
Wanderers(%)
Dispersal (every rodents)
Mean (x100m)
Max (x100m)
Inbreeding (FIS x100)
Console output
01/03/2019 (tick 2666): Cultural Practice
01/04/2019 (tick 2914): Start/end of breeding season
01/04/2019 (tick 2914): Cultural Practice
01/05/2019 (tick 3154): Cultural Practice
01/06/2019 (tick 3402): Cultural Practice
01/07/2019 (tick 3642): Cultural Practice
01/08/2019 (tick 3890): Cultural Practice
01/09/2019 (tick 4138): Cultural Practice
01/10/2019 (tick 4378): Cultural Practice
01/11/2019 (tick 4626): Start/end of breeding season
01/11/2019 (tick 4626): Cultural Practice
01/12/2019 (tick 4866): Cultural Practice
01/01/2020 (tick 5114): Crop Transition
01/01/2020 (tick 5114): Cultural Practice
01/02/2020 (tick 5362): Cultural Practice
Console Error
© 2016 Google
Populations
Rates
dispersals (home range size)
SIMmasto0: raster Chize
FIS
Parameters
Run Options
Running
SimMasto

Overall result for agents' dispersal



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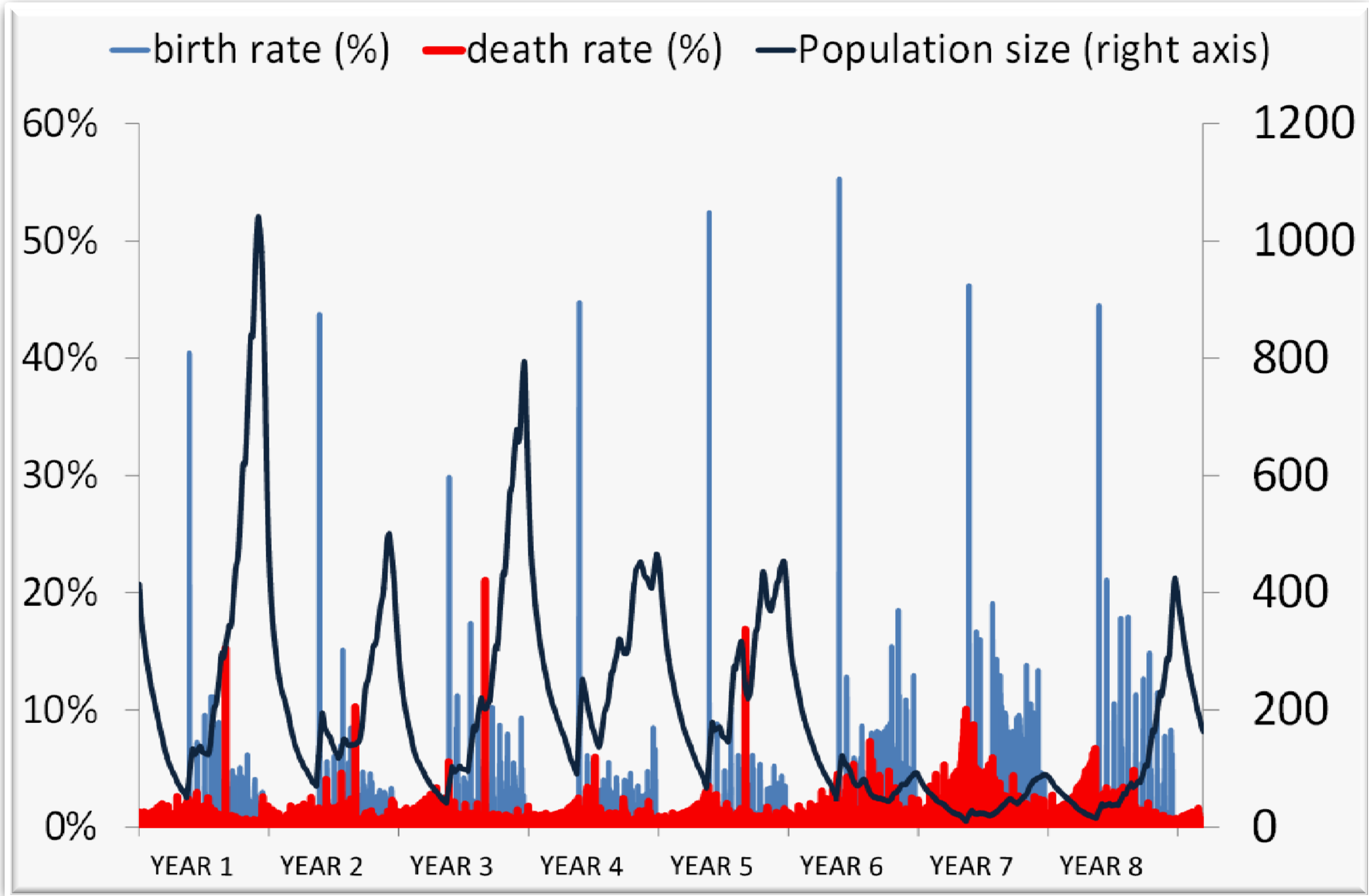
Overall result for population



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Conducting a time scale sensitivity analysis

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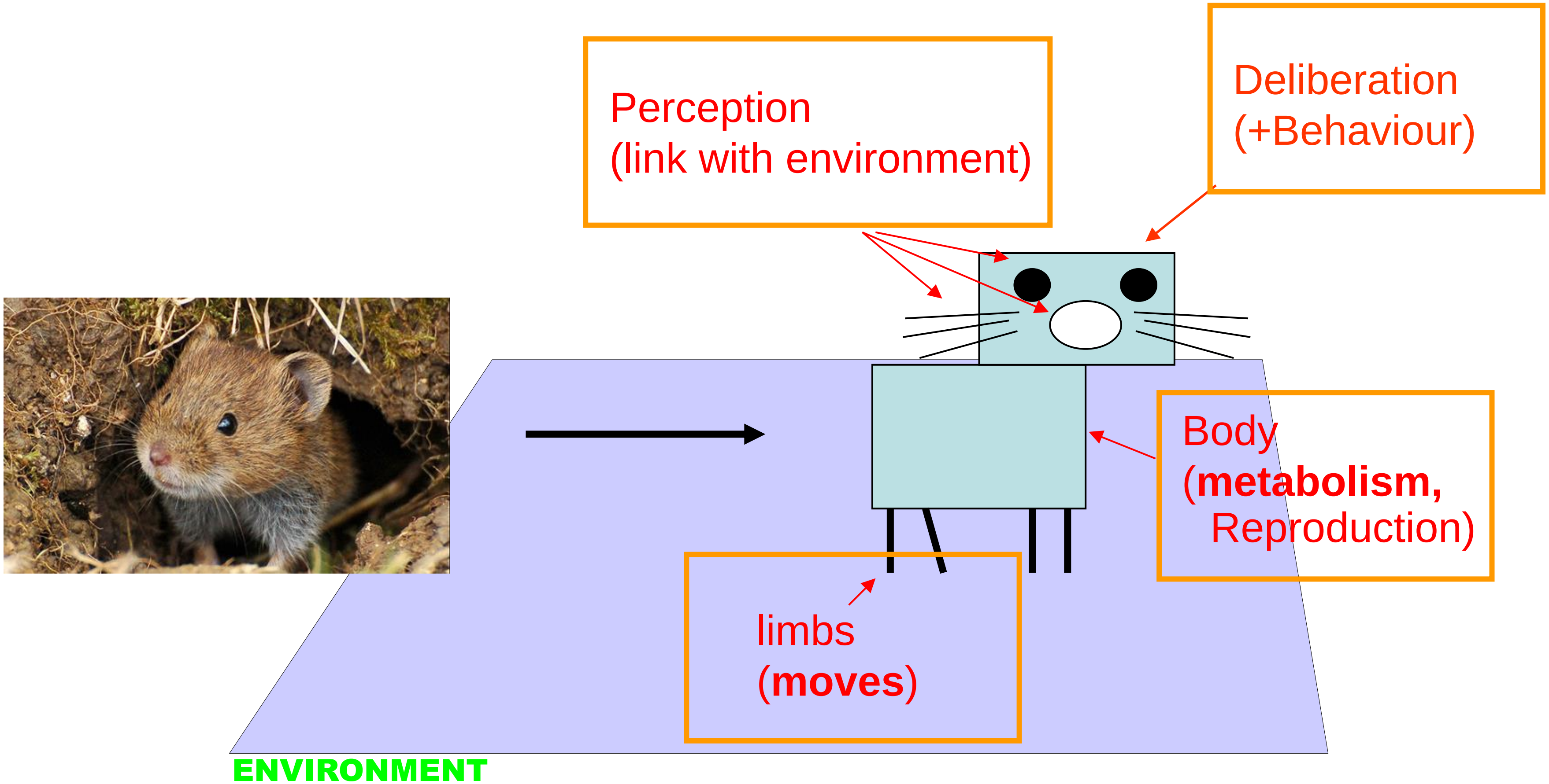
1./ Relative conversion of time-related mechanisms



2/ Sensitivity Study Protocol

- Simulations are run using three ranges of time steps:
  1) from 5 min to 90 min each 5 min,
  2) from 90 min to 48 hours each 10 min and
  3) from 48 hours to 9 days each 30 min.

- Three constraints imposed to stop simulations.
  1. maximum population of 6.000 individuals (signing a pullulating population)
  2. No female remains (signing a collapsing population)
  3. If none of the above:
     Stop at 3 years simulation duration
     - Simulations are stopped at the beginning of the reproduction season where rodents' population is at its lowest.

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Results

Time step sensitivity analysis

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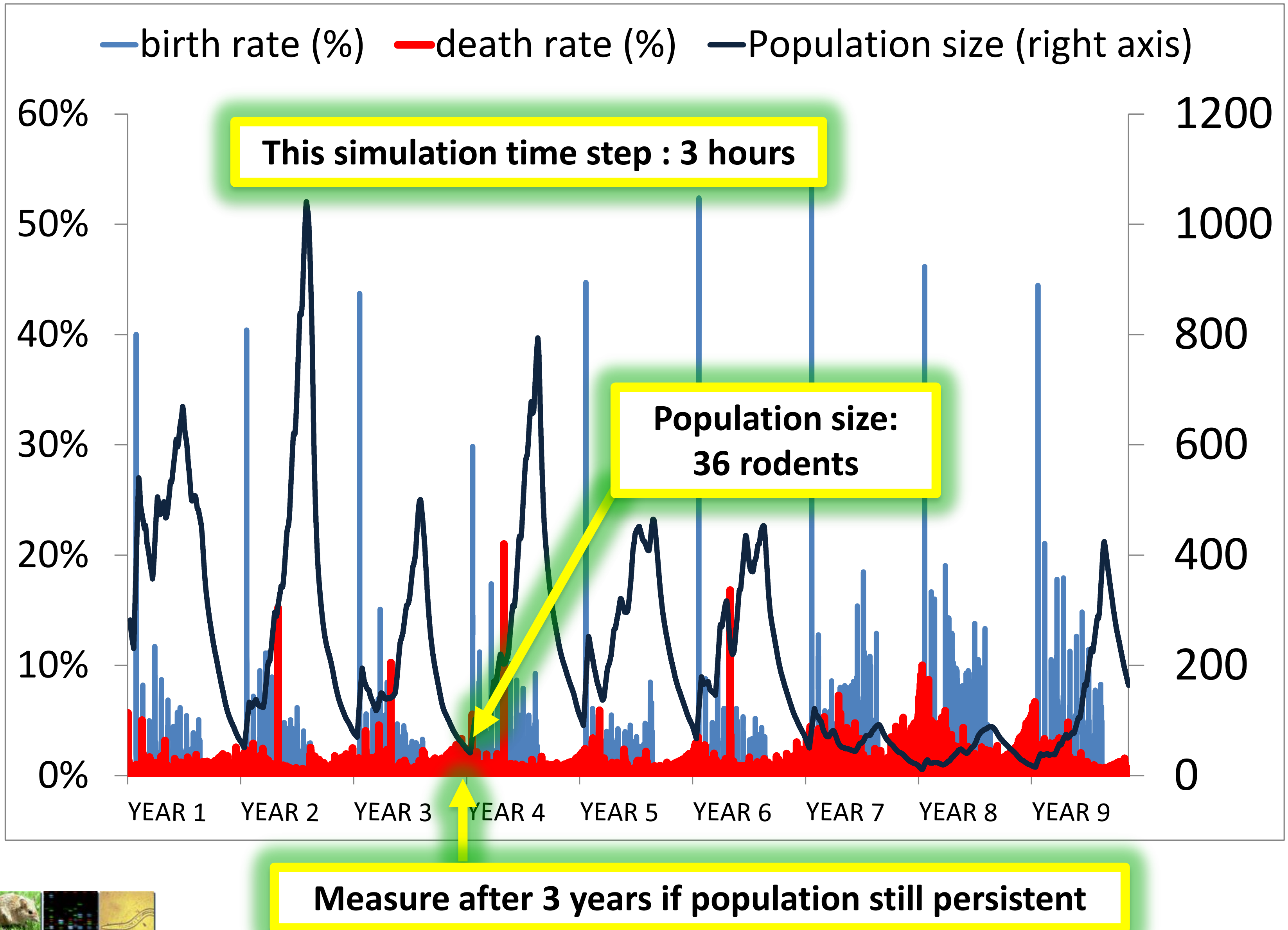
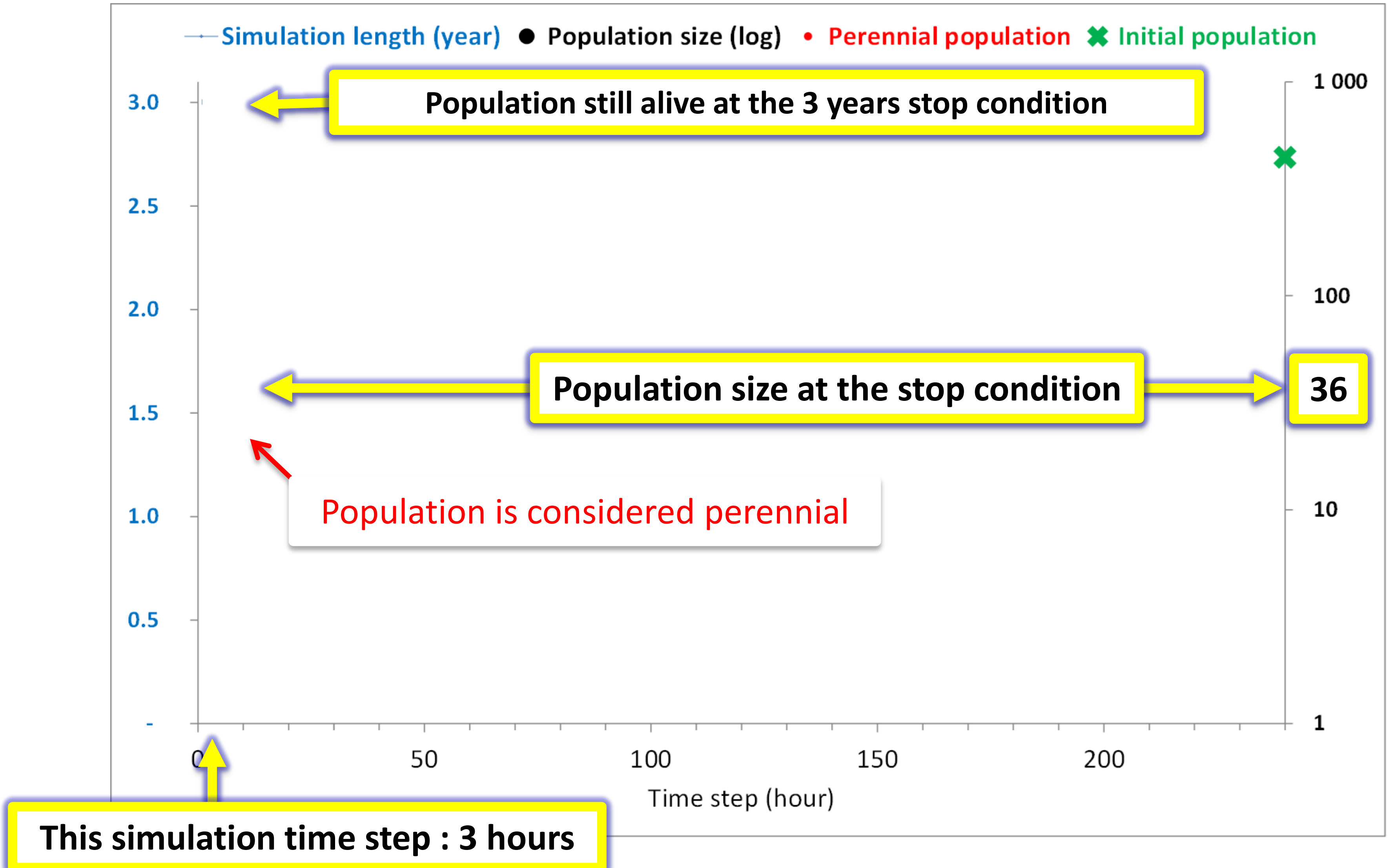
Building the graph



Building the graph



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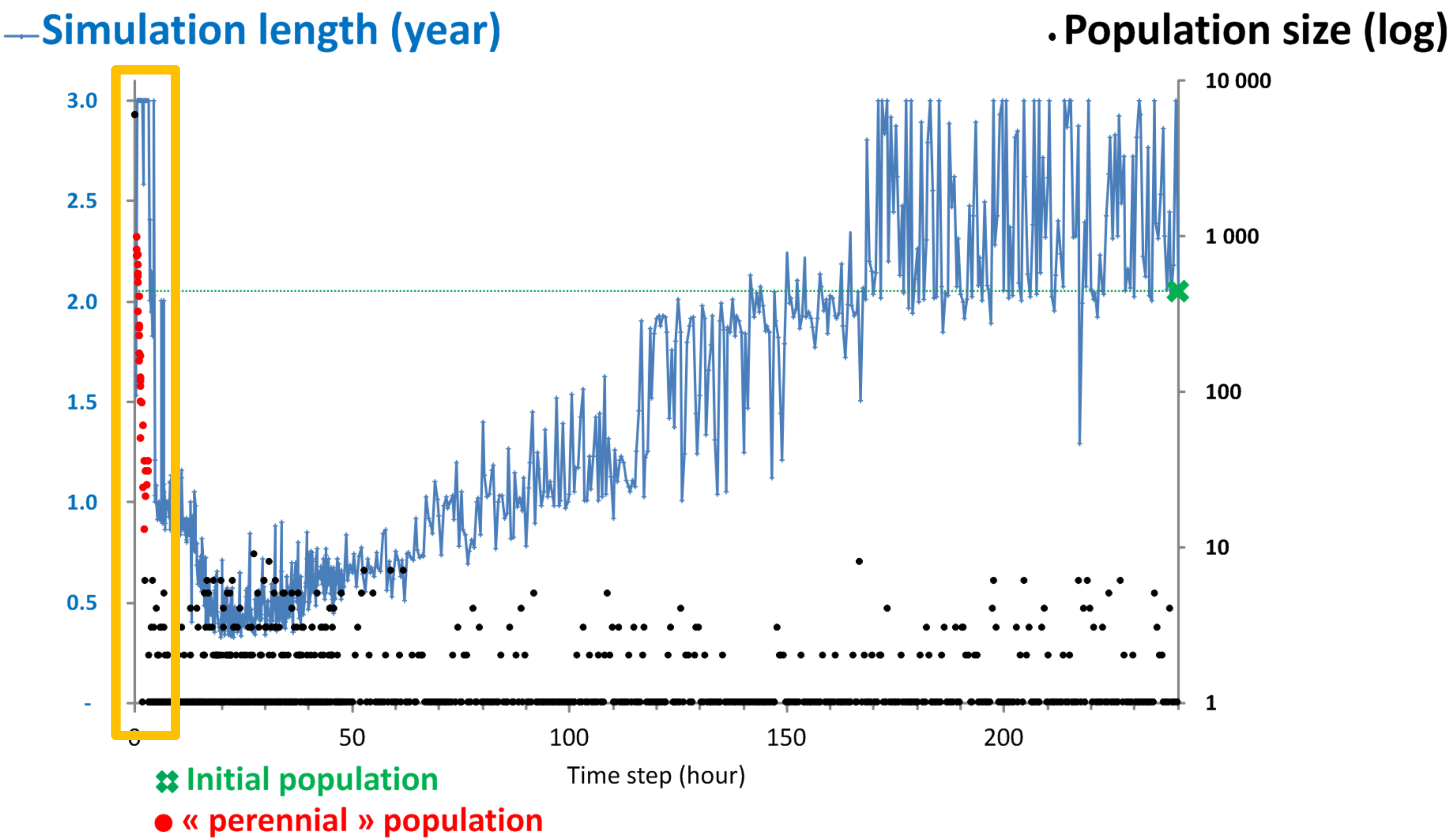
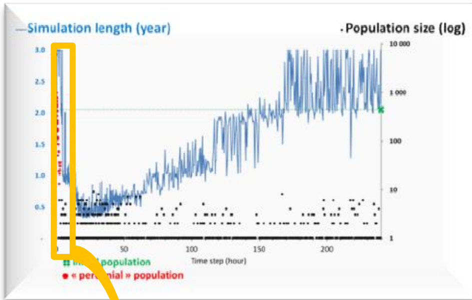
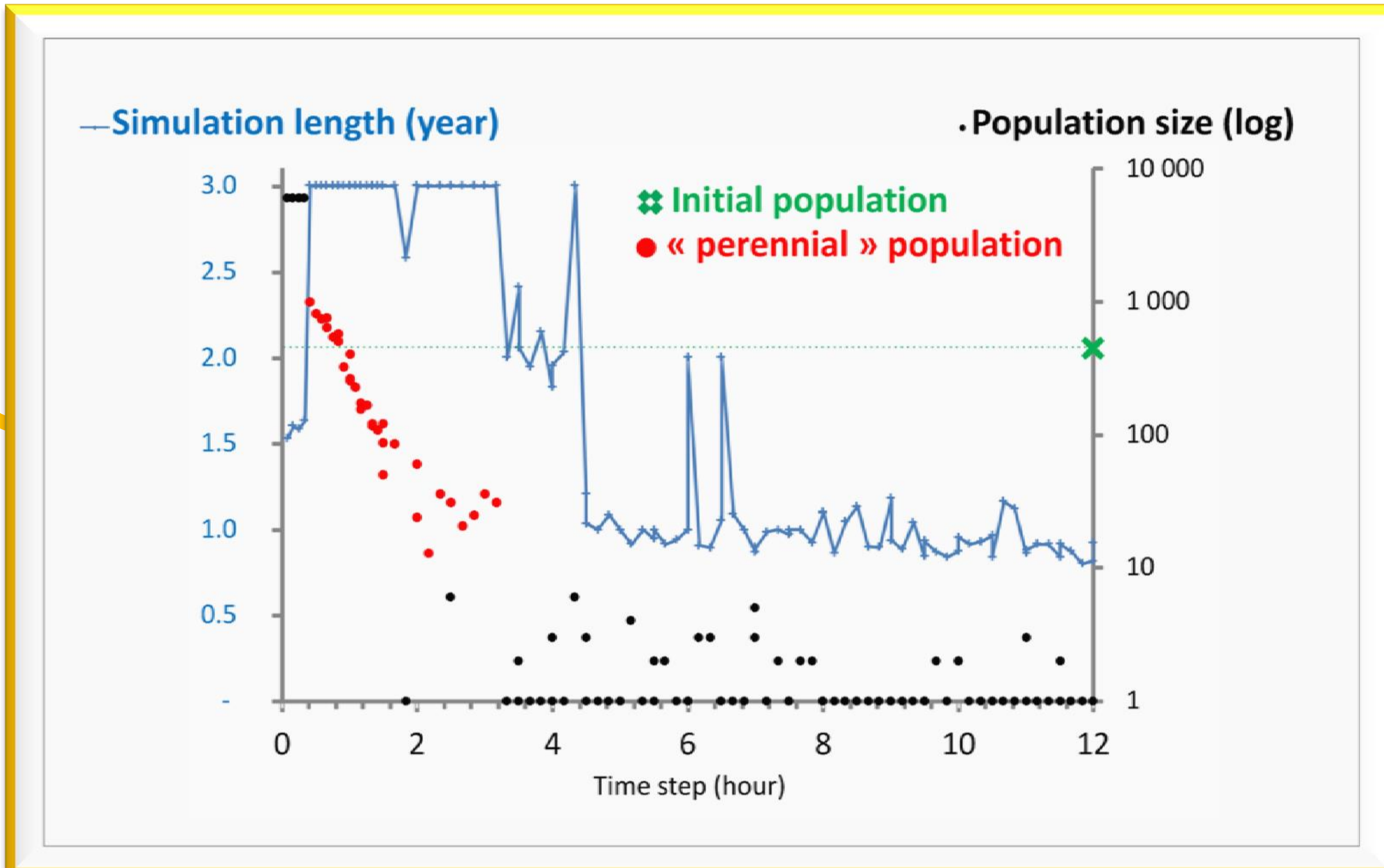
Selected output indicators of the time step sensitivity analysis



‘perennial’ range of frequency suggests that rodents in the simulated environment would have to perform a decisive deliberation process from each 30 min to each 3 hours





Discussion

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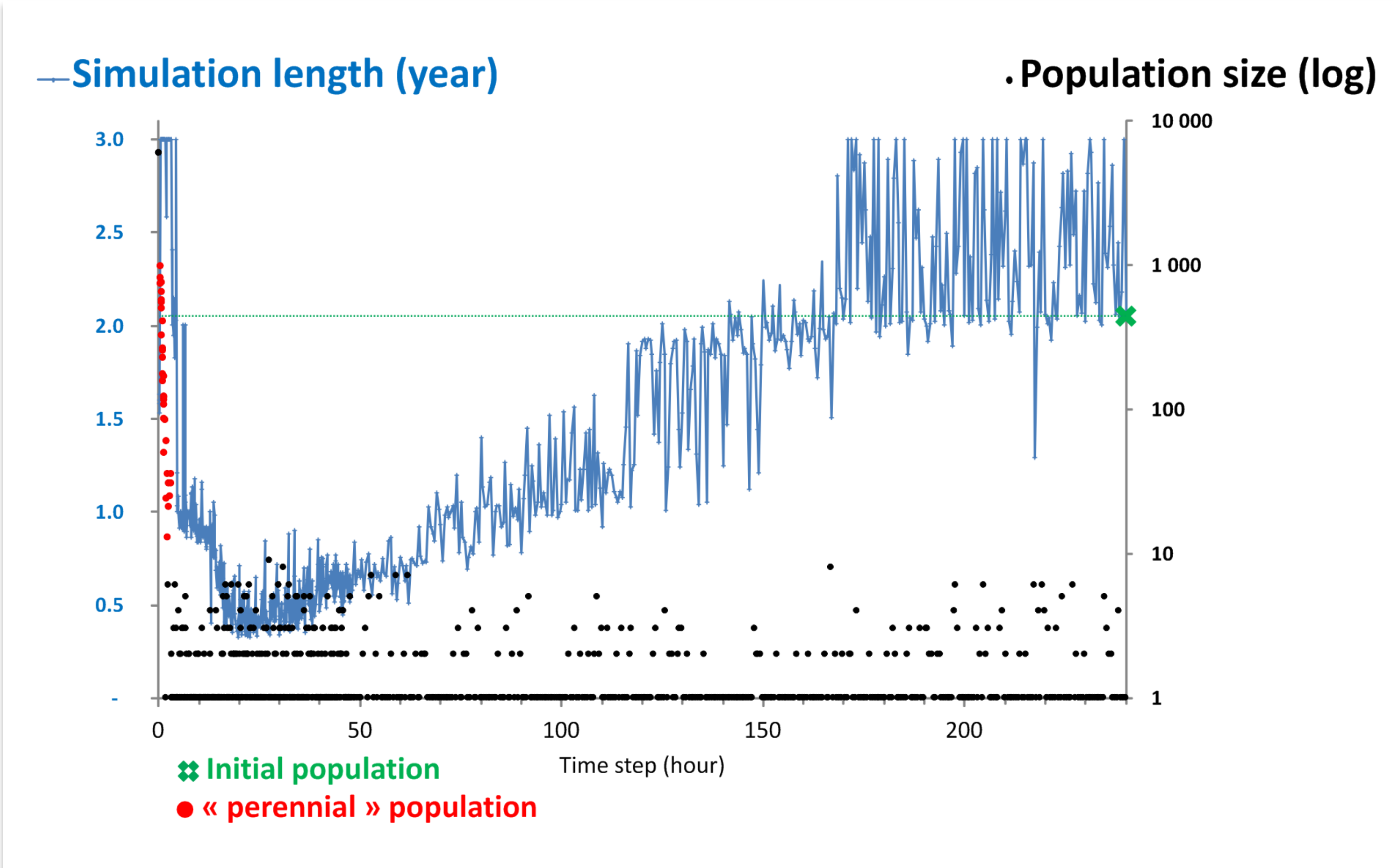
CAUTION, results are indicative

Single parameter sensitivity analysis

Results obtained “all other things being equal otherwise”

Q: In an ideal scheme, the simulated population dynamics and indicator values would remain unchanged whatever the time scale chosen



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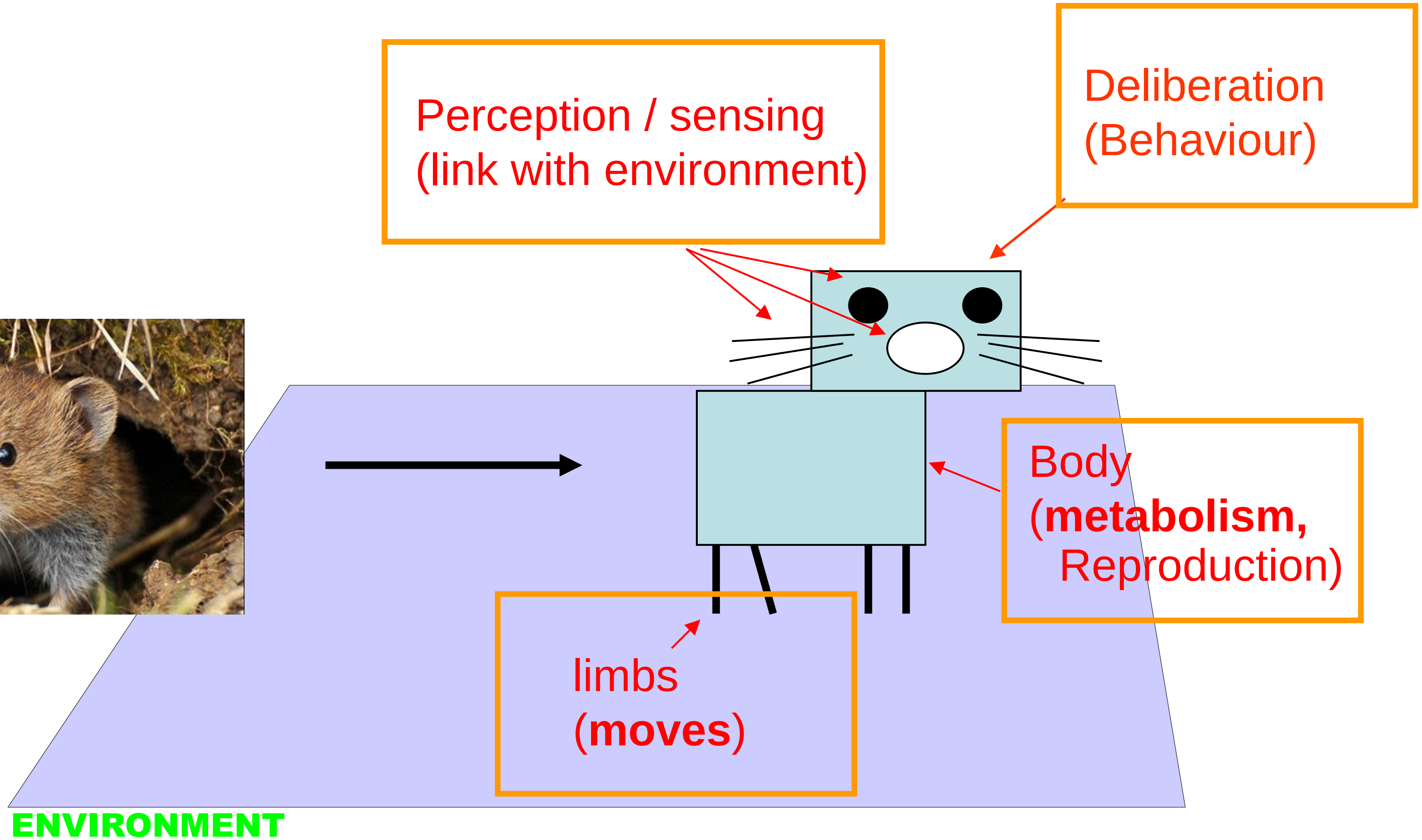
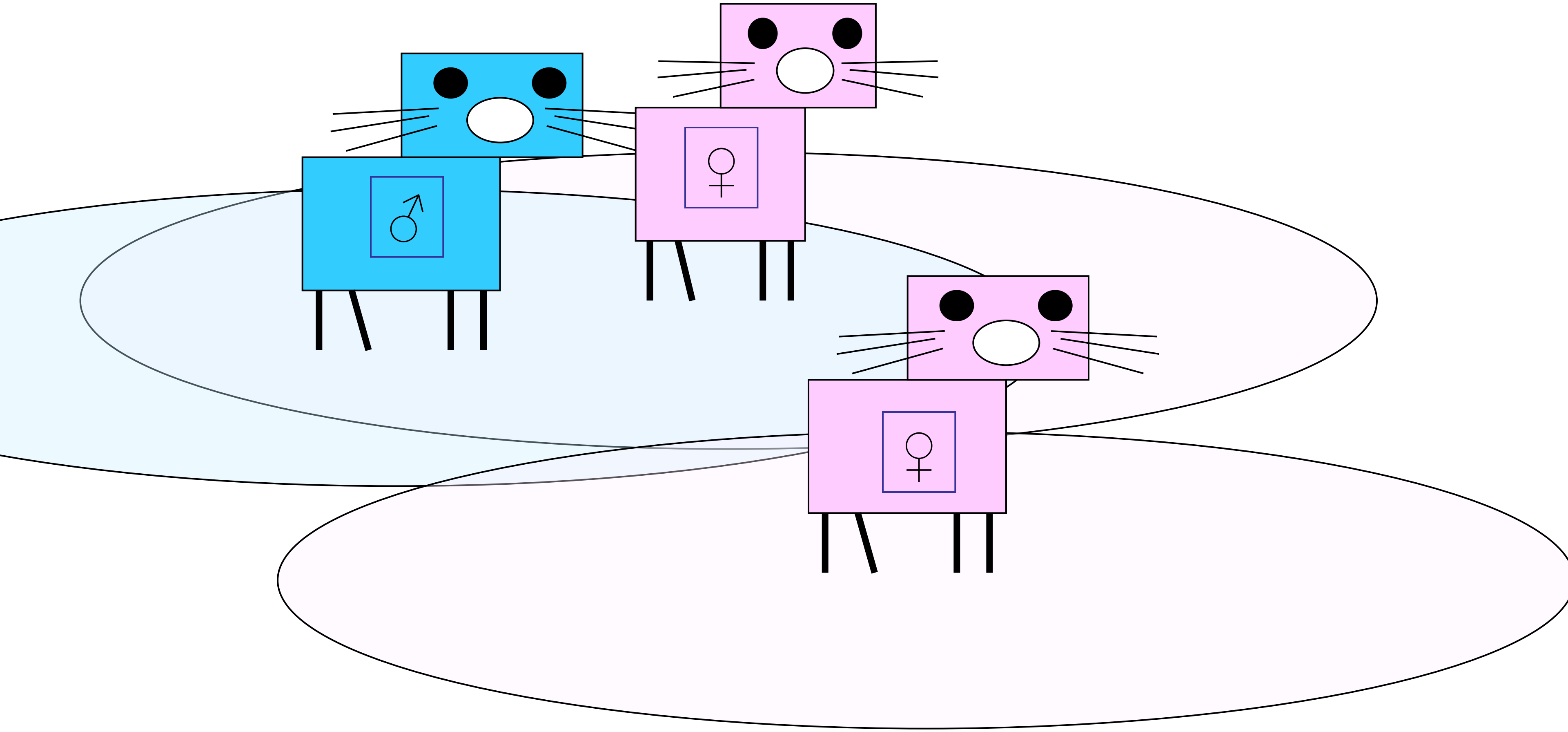
Sources of discrepancies/biases - Time-related mechanisms



Sensitivity to environment perception



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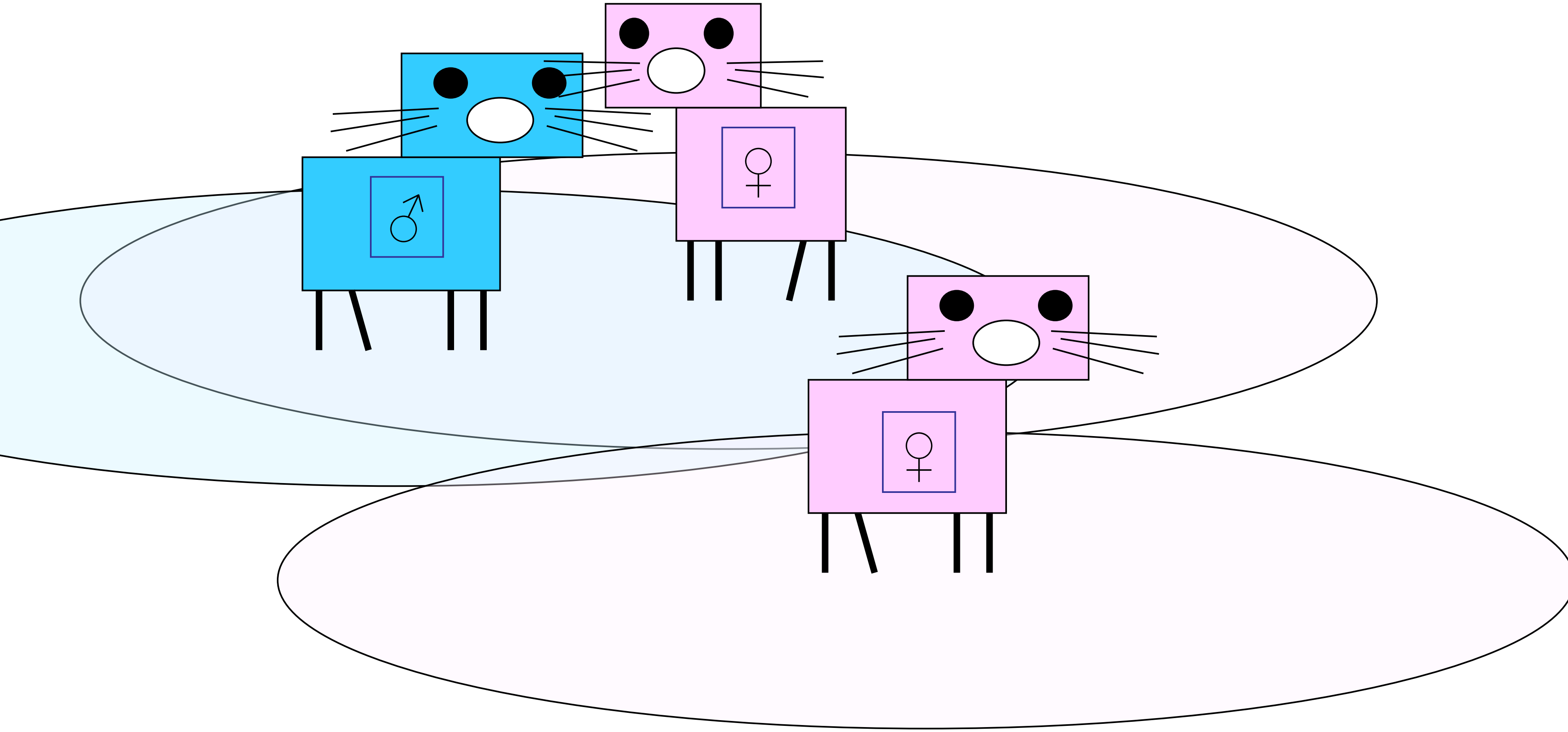
Sensitivity to environment perception



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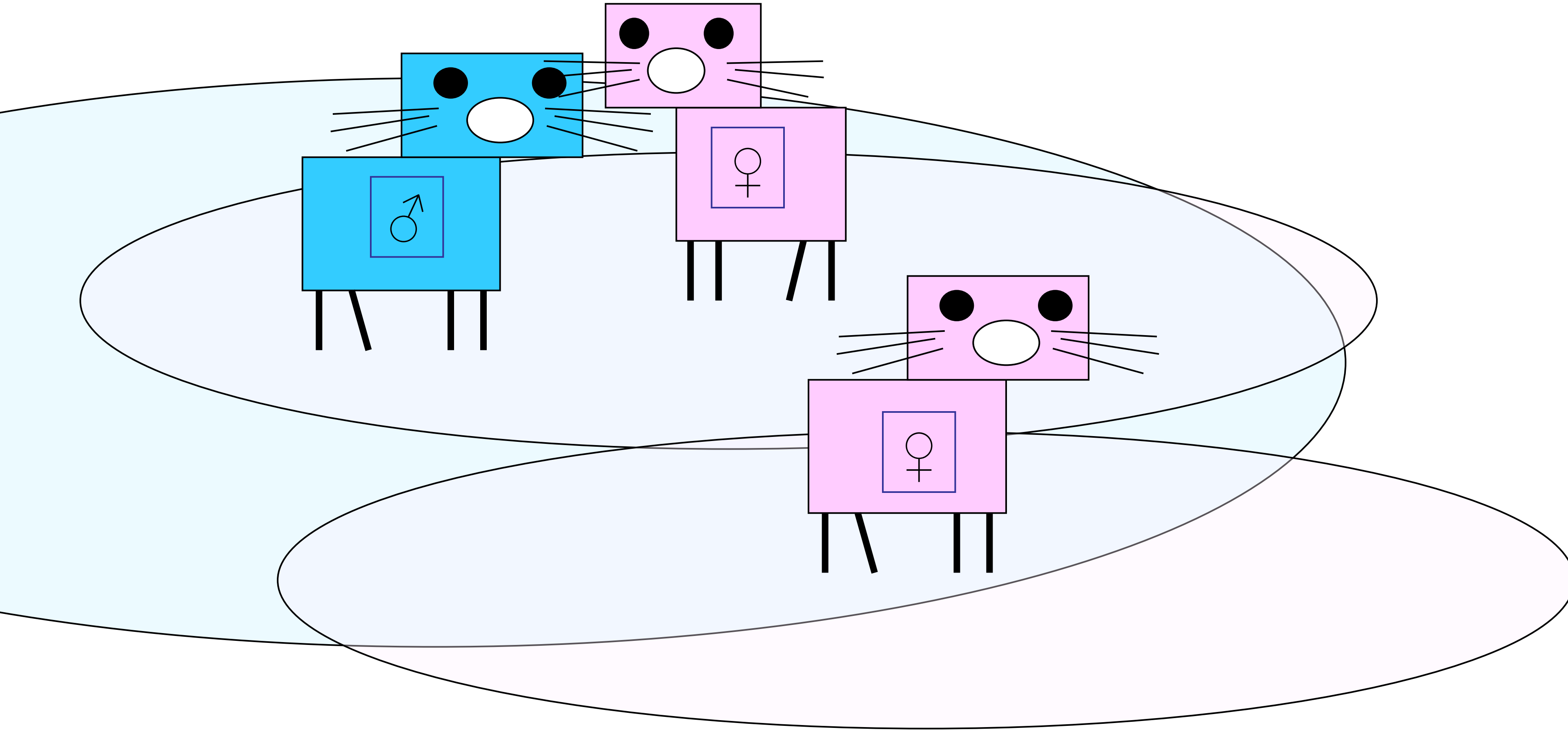
Sensitivity to environment perception



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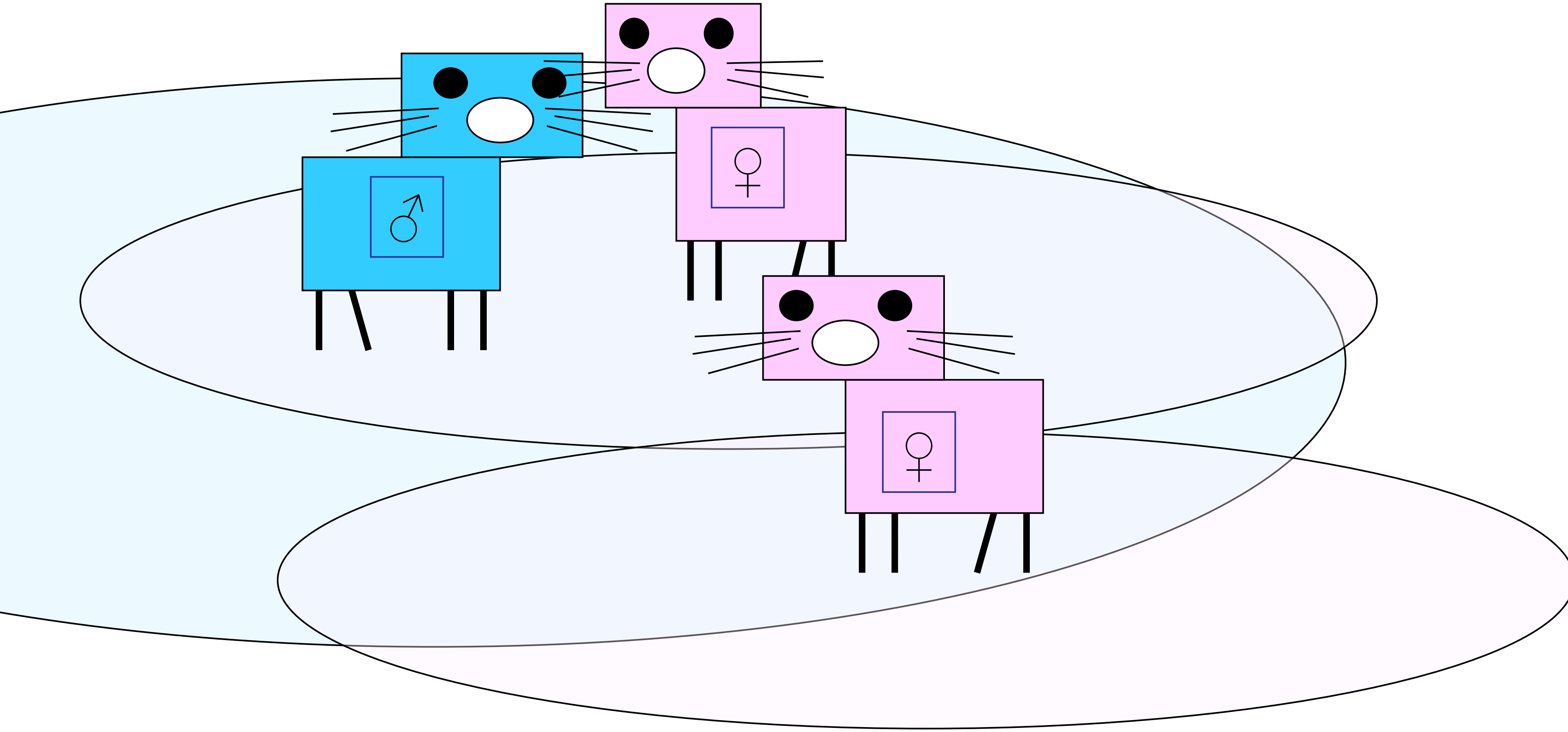
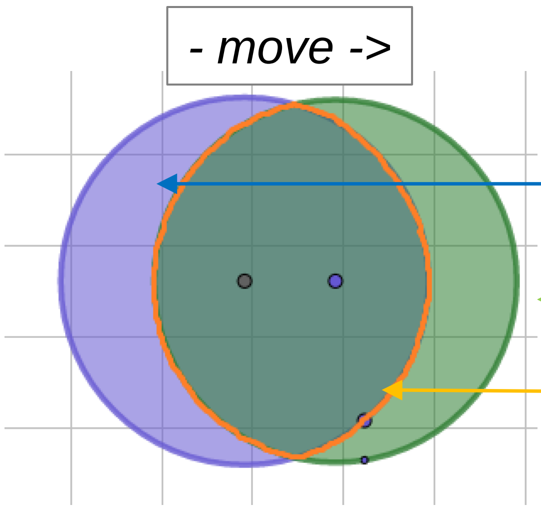
Sensitivity to environment perception



Is computing sensing as a function of perception circle radius is appropriate ?

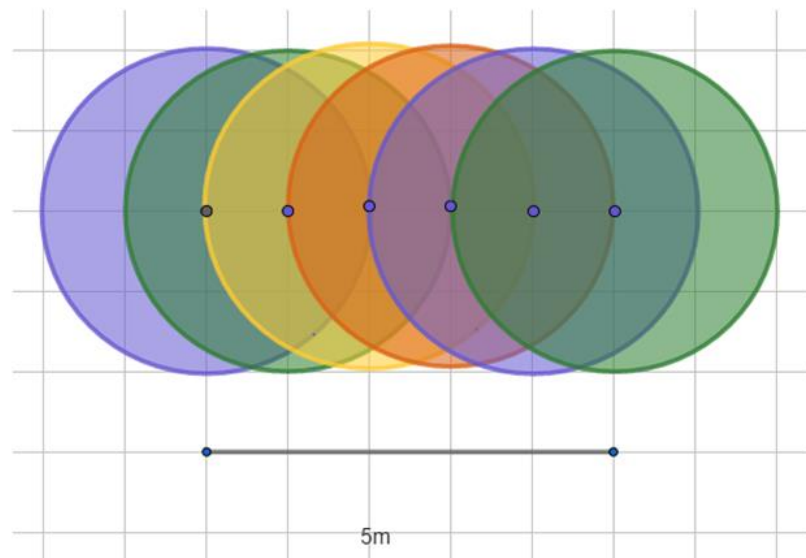


Perception area tick n-1

New perception area tick n (*lunule*)

perception area shared during the 2 ticks (*lens*)

In simplified straight line move
The cumulative sum of sensing areas is greater than the corresponding one at a larger tick



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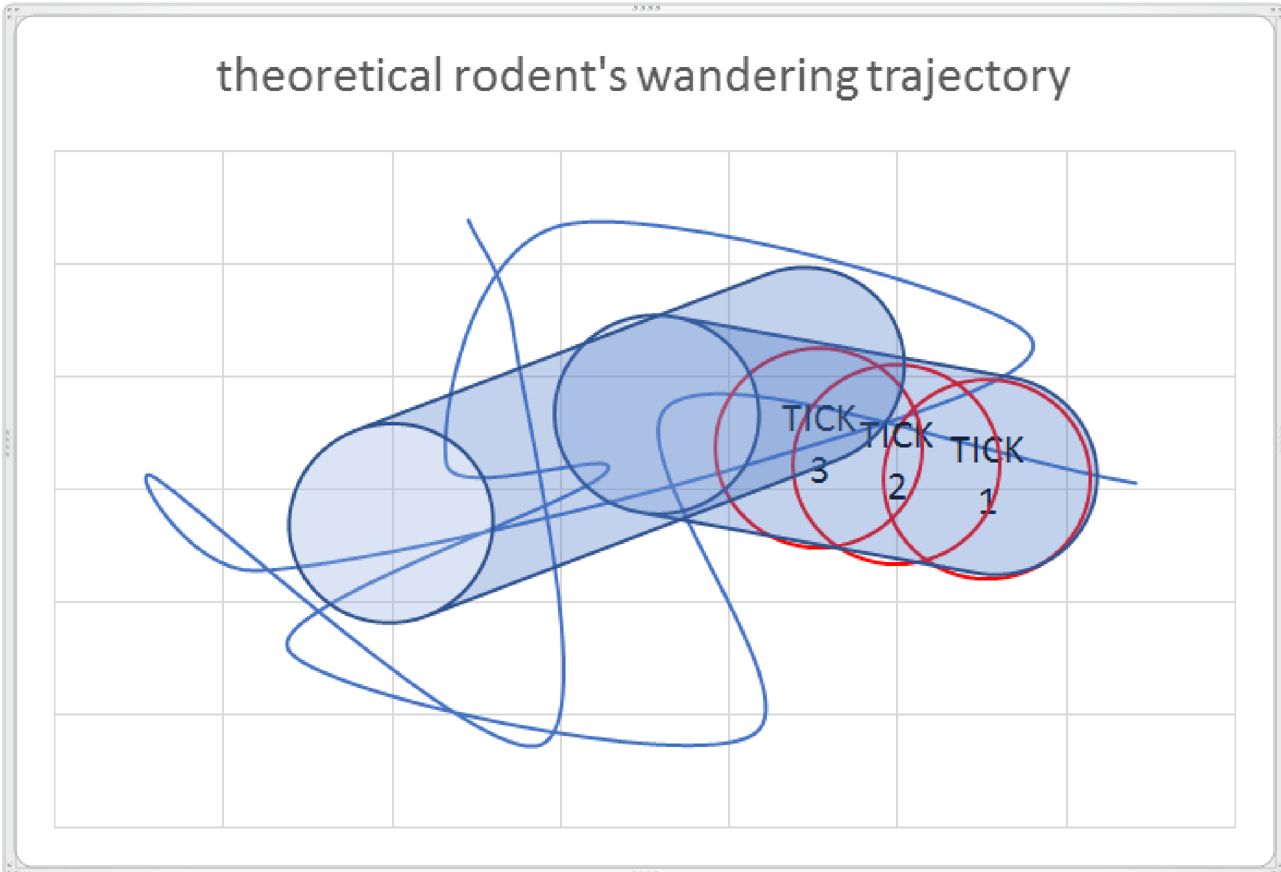
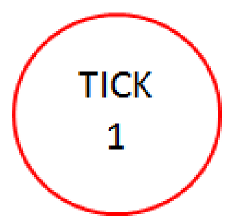
However, rodents' trajectories are seldom linear



Perception area within the first tick



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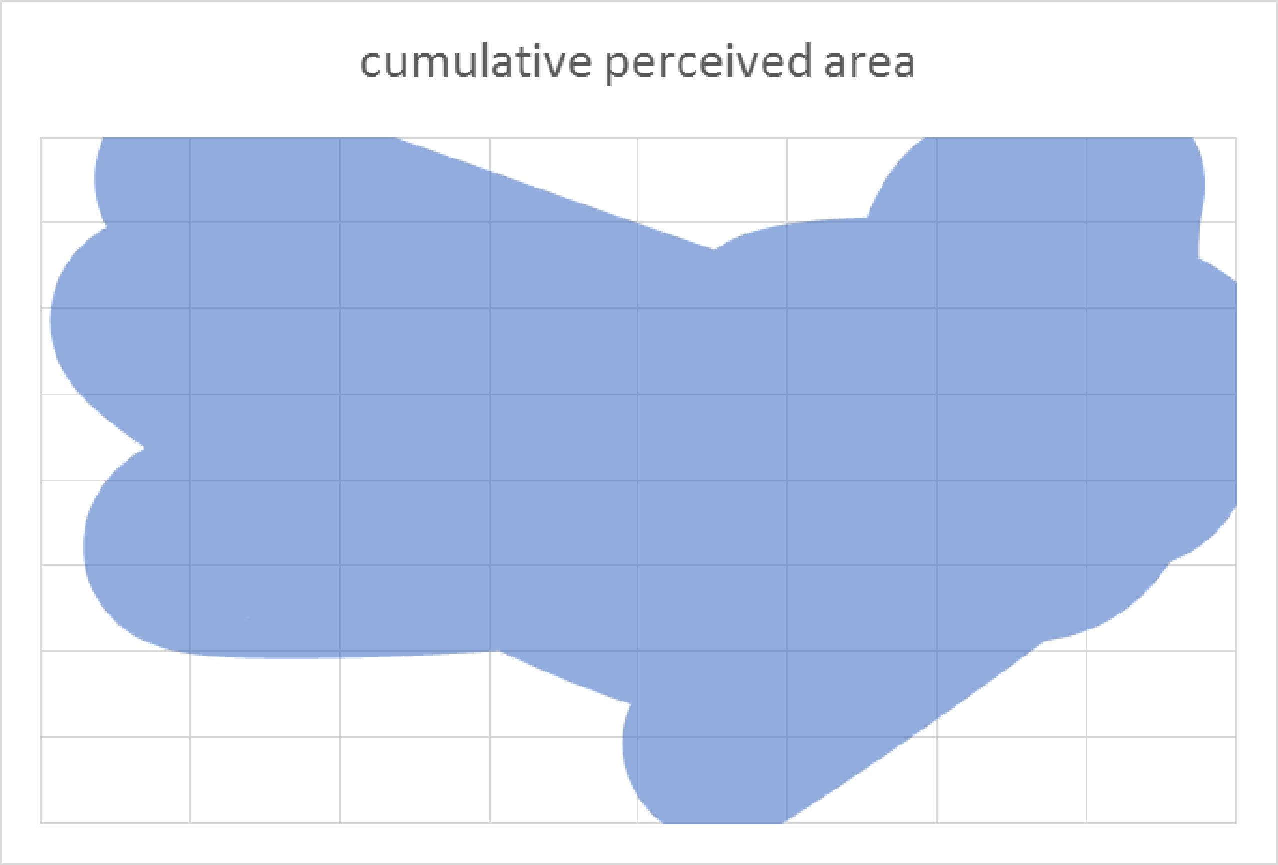
Travelled area then decreases and converges toward the same order of magnitude that the integrated circle



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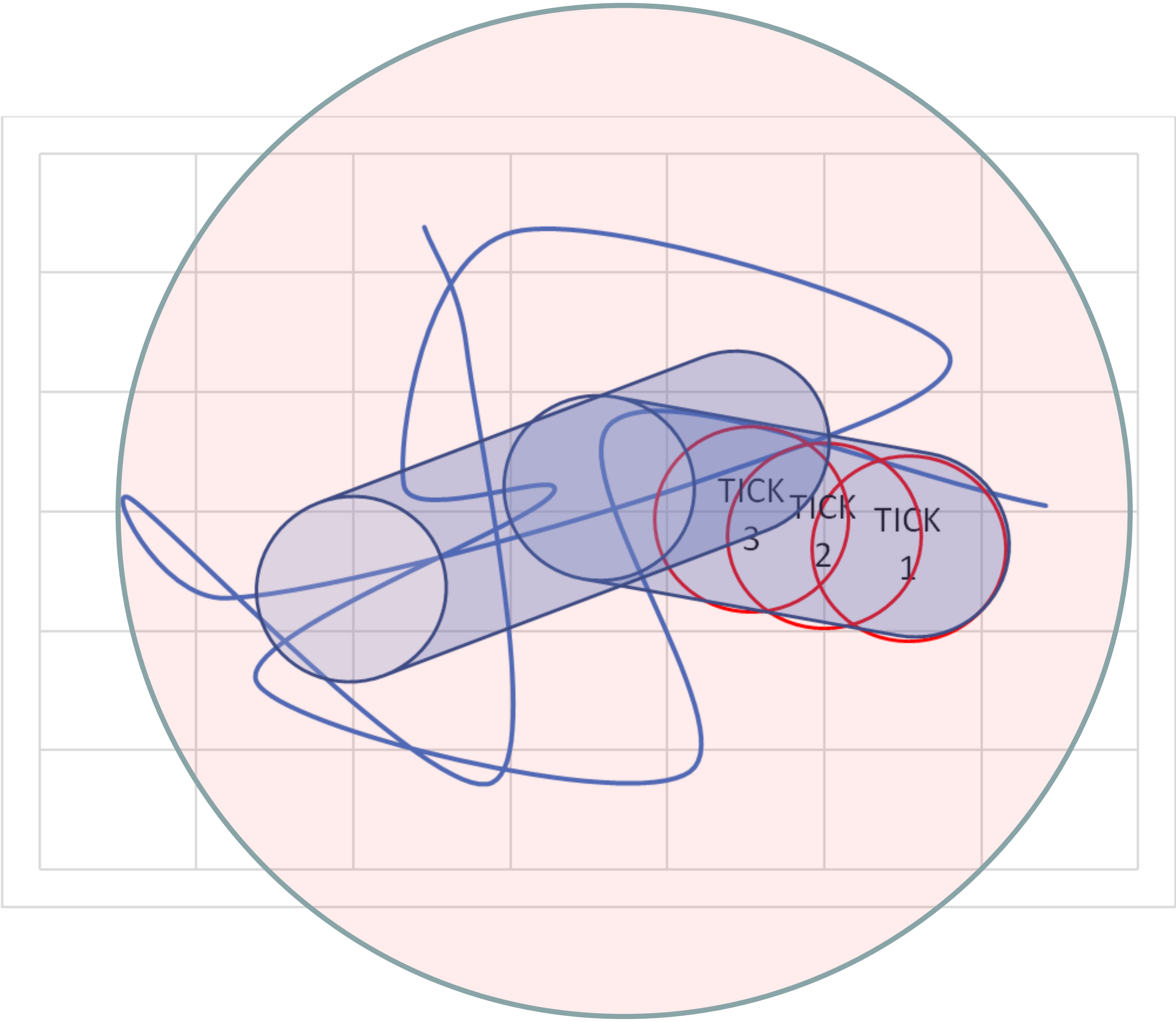
In any case, perception depends on the rodent's trajectory



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Conclusion

What is the convenient time step for such model ?

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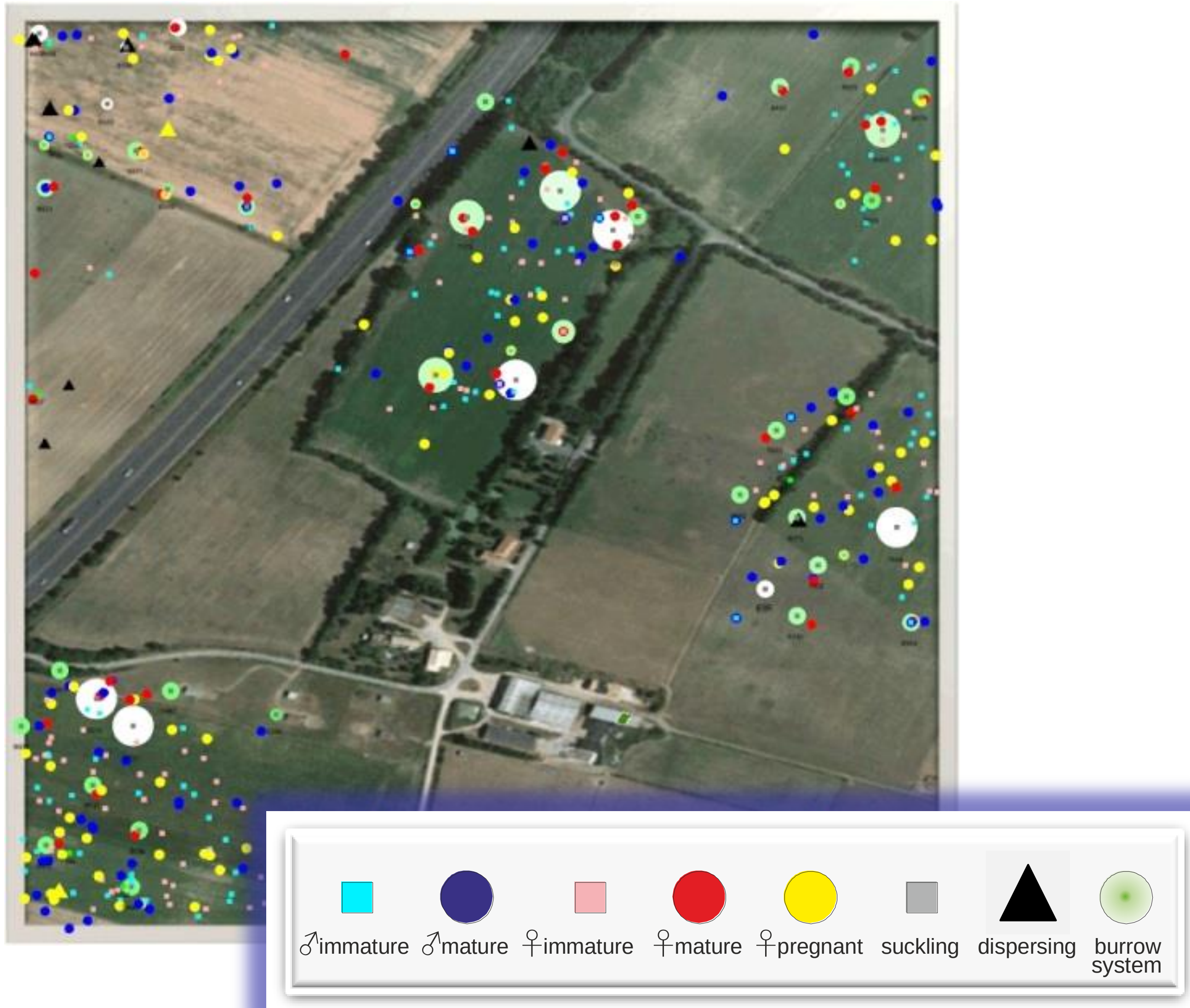
Use case example :

What is the convenient time step for one model ?

Situation after only 1500 steps (6 months)

Time step :
180 min
(3 hours)



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What is the convenient time step for one model ?

Use case example:

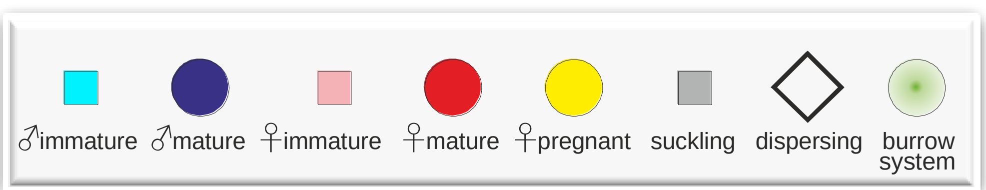
Situation after only 1500 steps (6 months)

Time step :

179 min

180 min
(3 hours)

181 min



Thank you for your kind attention