Improvement of emergency vaccination strategies against rabies in red fox populations with the help of CA & ES

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  - The rabies eradication program
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Rabies – Past & Present

- Rabies is a zoonosis
  - 6 human cases in 2003 in Europe
- Main reservoir
  - Wildlife Red Fox *Vulpes vulpes*

Fox Rabies – Past (1990)

The Rabies eradication program

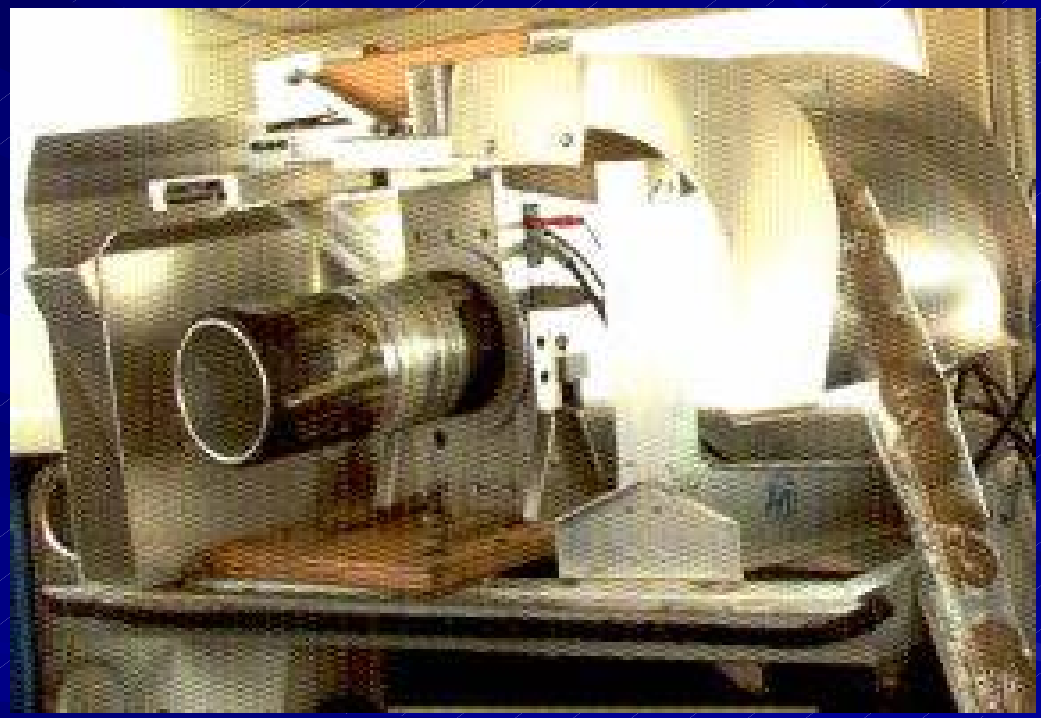
- Foxes are orally vaccinated
  - Vaccine laced baits

The rabies eradication program

- Large scale distribution of vaccine baits

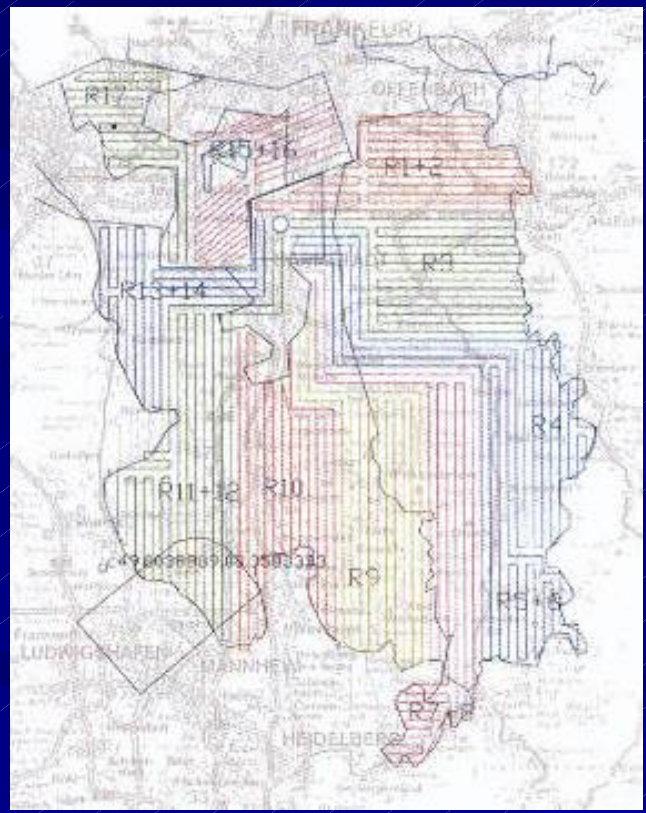
The rabies eradication program

- Automated distribution of baits

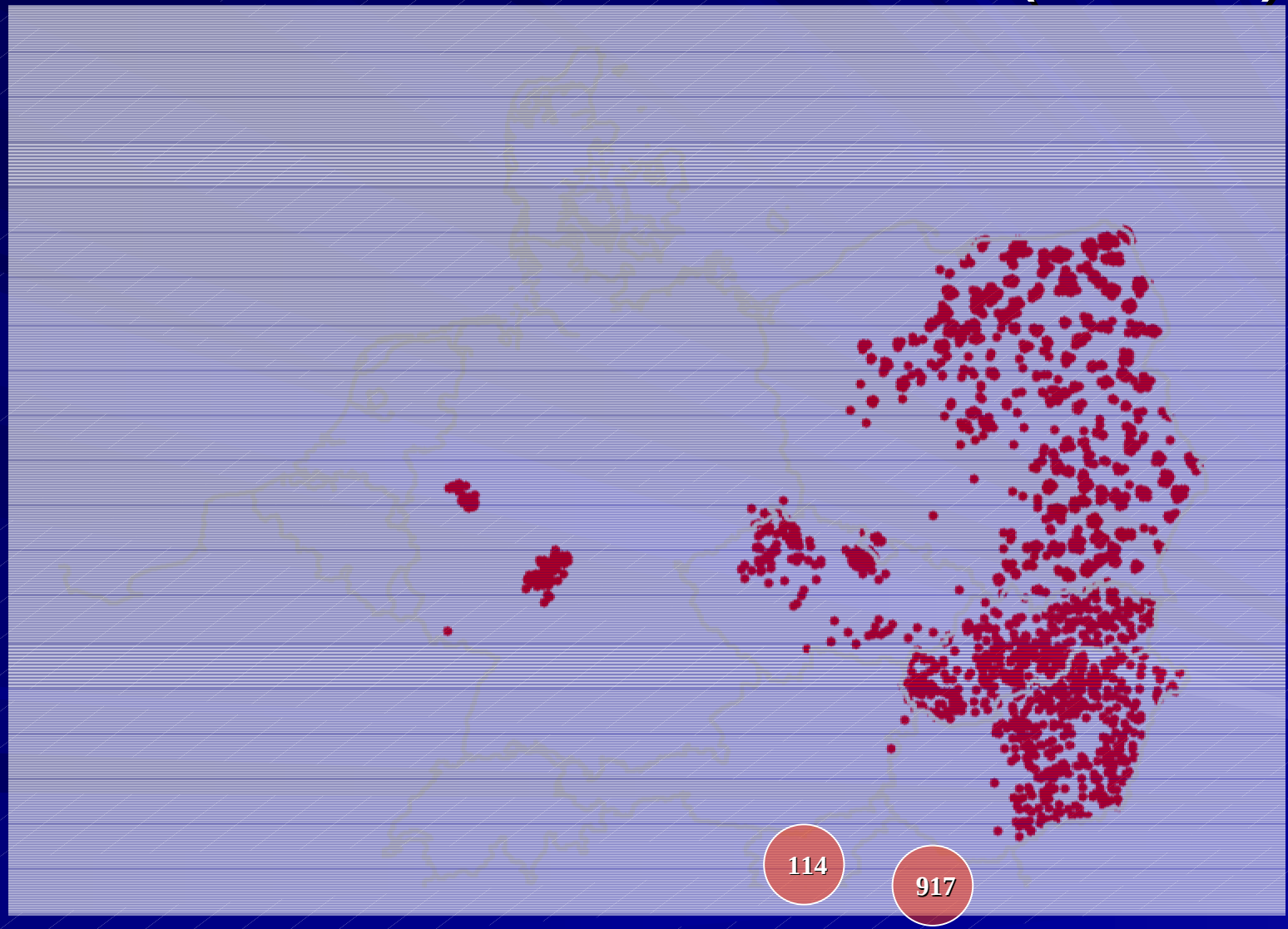


The rabies eradication program

- Large scale coverage with vaccine baits

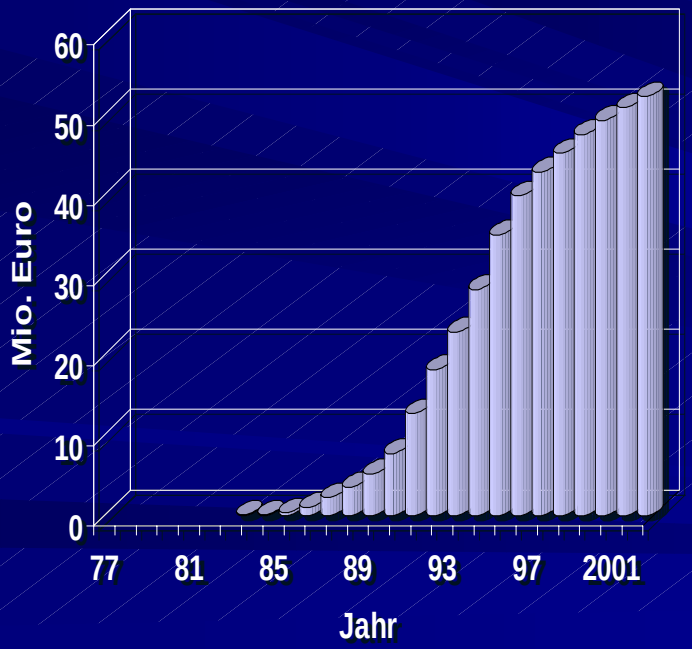


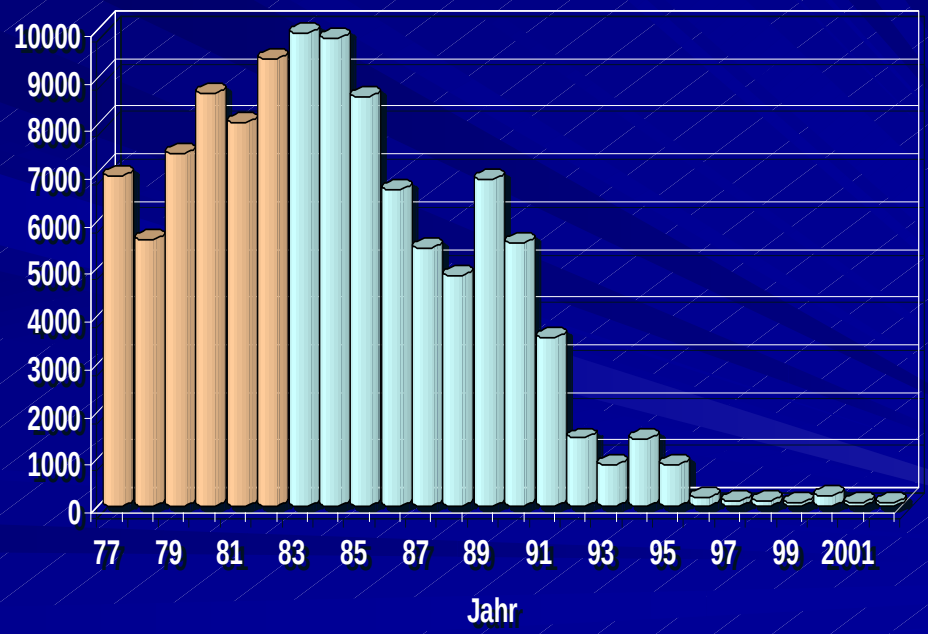
Fox Rabies – Present (2000)



Rabies eradication

- The costs and benefits





New challenges and Solutions

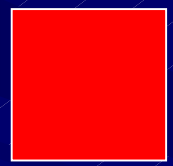
- Challenge
  - Clearance of new outbreaks at minimal costs
- Solution
  - Develop candidate strategies using
    - CA for rabies infection dynamics in time und space
    - EA for optimizing vaccination strategy in space
  - Only test candidate strategies under field conditions to reduce cost of development

Basic Fox ecology

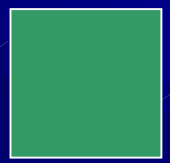
- Foxes …
  - establish territories
  - territories accommodates fox families (vixen plus offspring)
  - size about 1 km² but density dependent
  - fight for territories during dispersal

Rabies infection dynamics in time and space

- Infection Status of a fox family

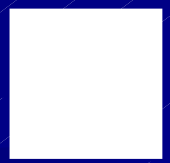


infected



healthy

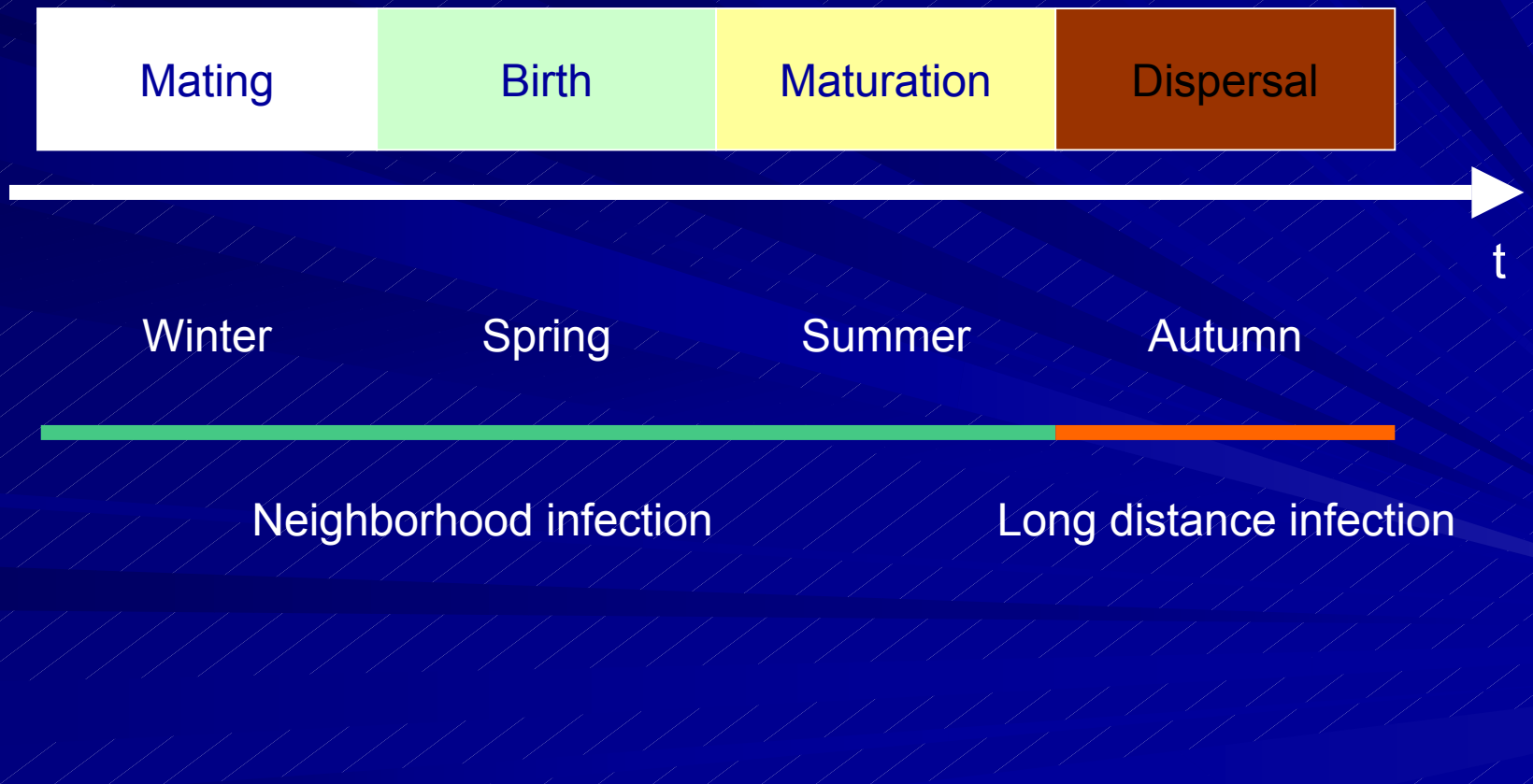
healthy + vaccinated



empty

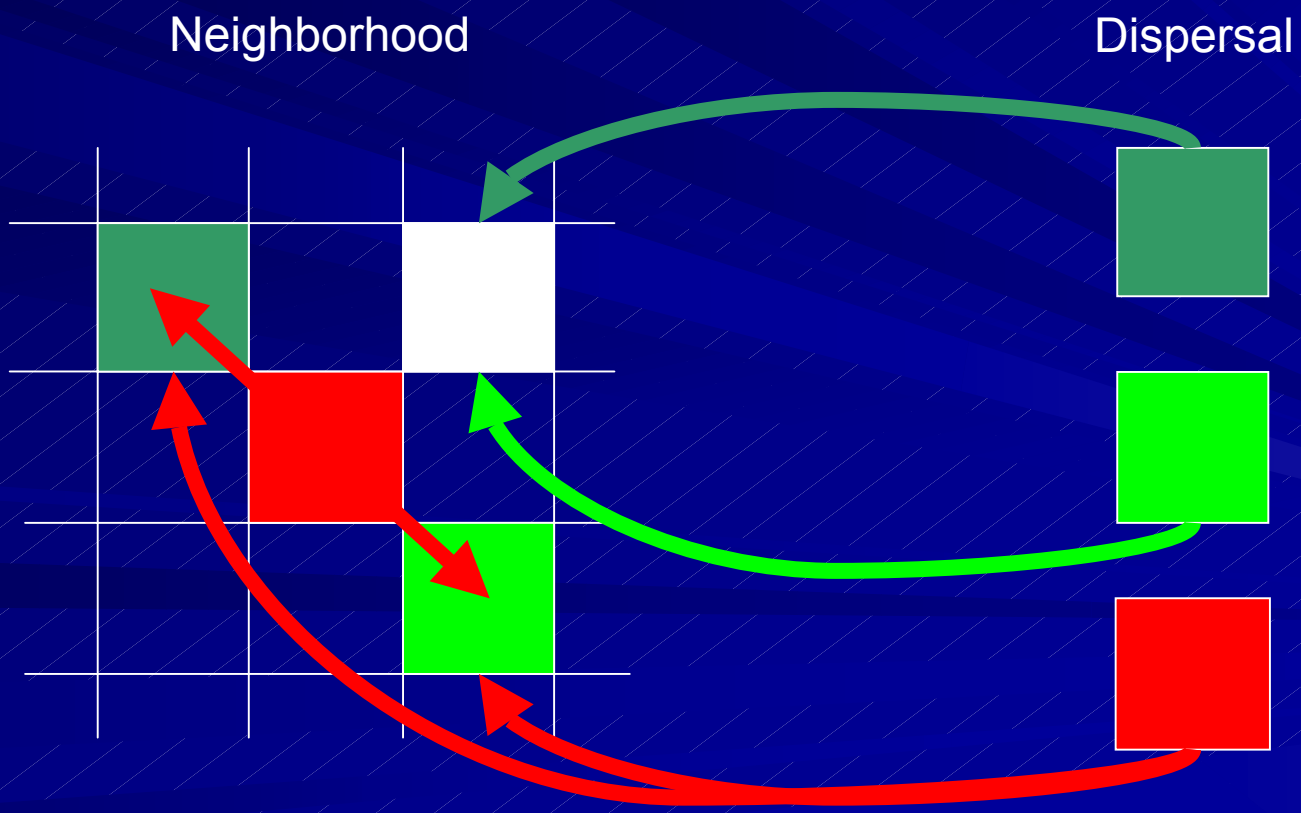
Rabies infection dynamics in time and space

- Infection and Time



Rabies infection dynamics in time and space

- Infection and Space

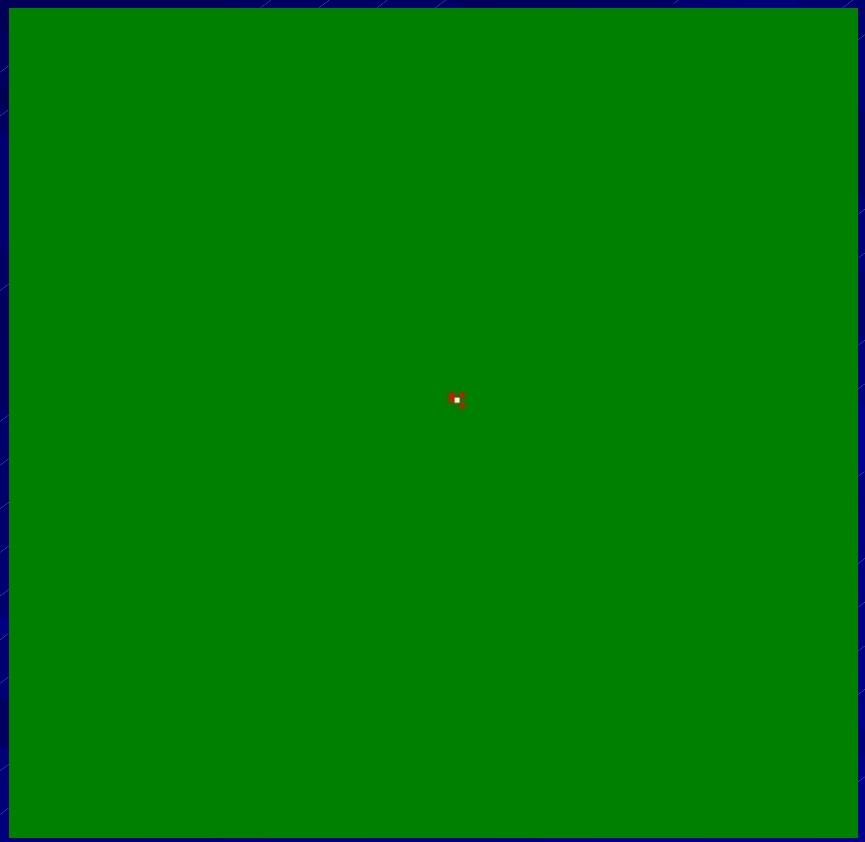


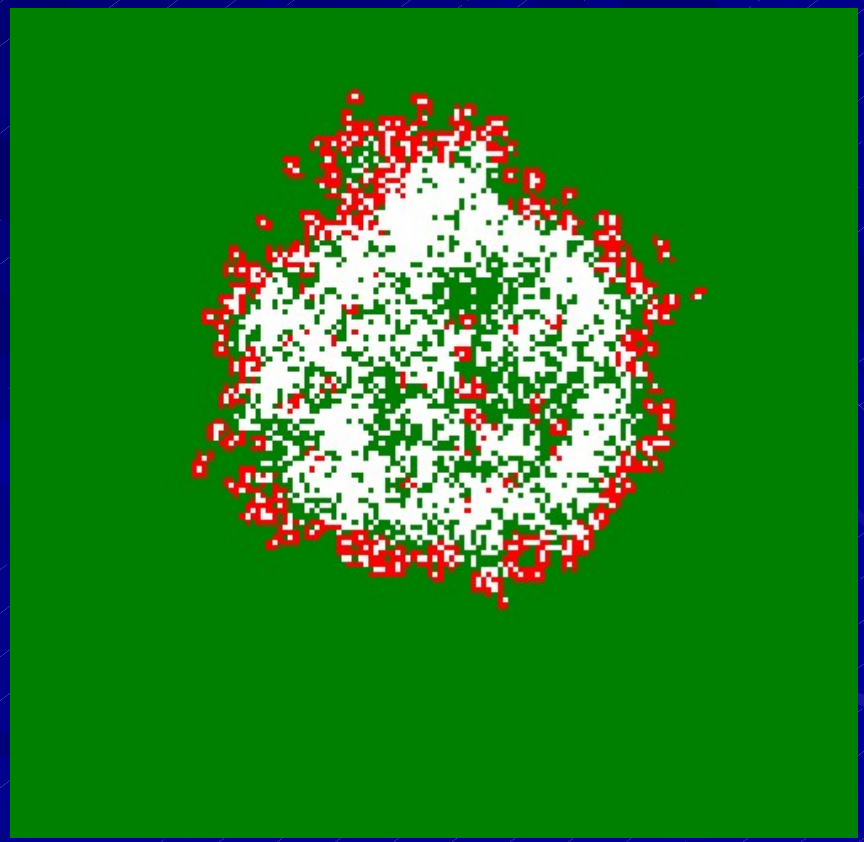
Simulated infection dynamics

- CA
  - 160 x 160 cells
  - Start with one center infected cell
  - Spatial dynamics
    - Neighbor infection
    - Dispersal infection
    - Foundation of new families (healthy)
  - Simulation time
    - 8 years with 4 seasons each

Simulated infection dynamics

- Example





Optimization

- Goal
  - Prevent rabies spread at minimal cost
    - encircle or combat?
    - Vaccination coverage [protection level / family] needed?
- Rabies spread
  - Number of infected cells at end of simulation
- Cost
  - Indirectly measure with vaccination coverage

Optimization

- Objective function

$$G(i) = \frac{\sum VC}{\exp(-n\,I)} \xrightarrow{!} \min$$

Optimization

- Evolutionary strategy
  - λ(15,100)
  - Mating
    - discrete for strategy parameters
    - intermediary (mean) for internal control parameters
  - Mutation
    - Strategy parameters: normal distribution
    - Control parameters: lognormal
  - Mass selection

Optimization

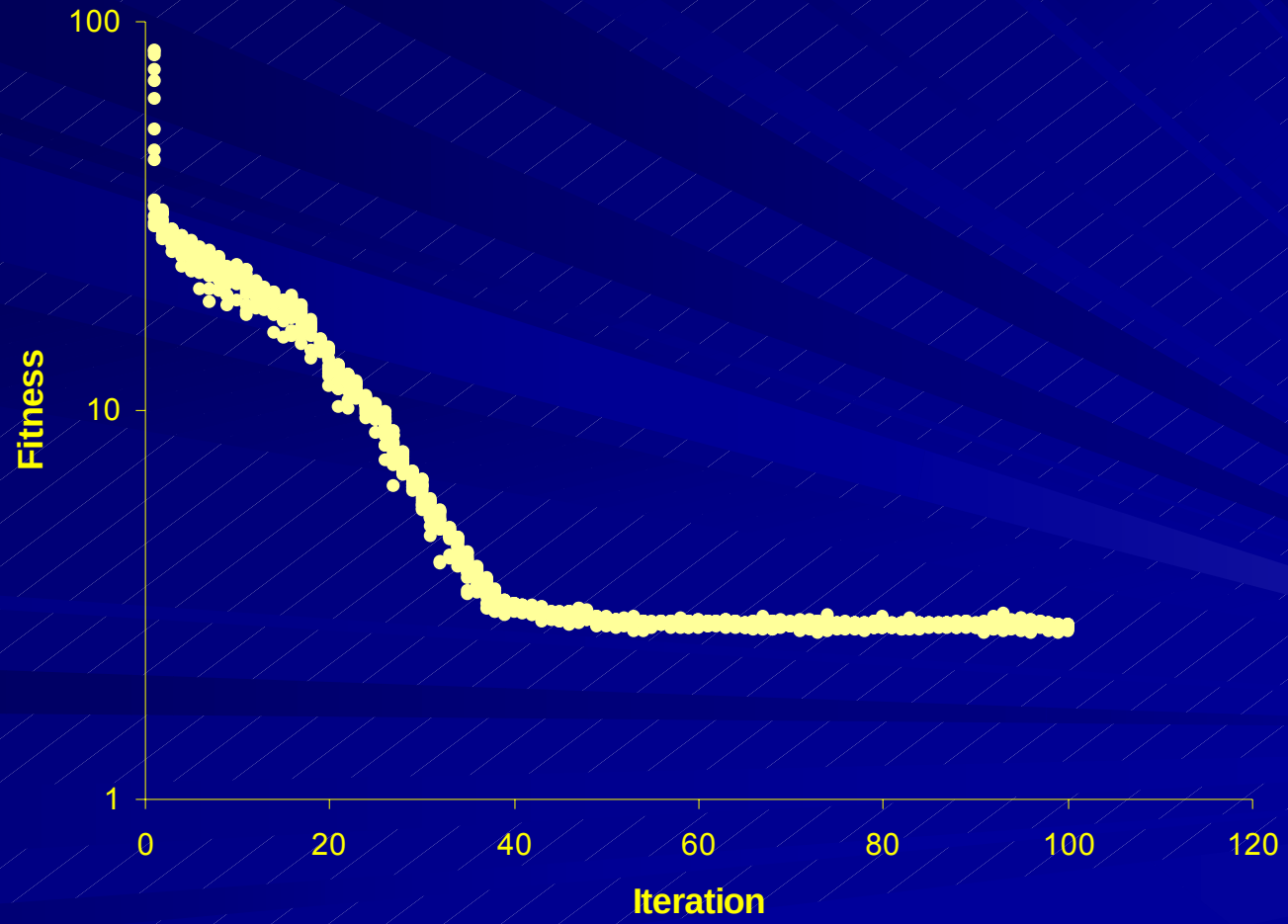
- Parameters
  - 8 x 8 = 64 parameters
  - 64 cells each cell represents 20 x 20 cells in the CA
    (it is not possible to vaccinate individual cells with aerial distribution)

Optimization scenarios

- Time to detection
  1. Immediately (first case)
  2. 1 year delay
  3. 2 years delay

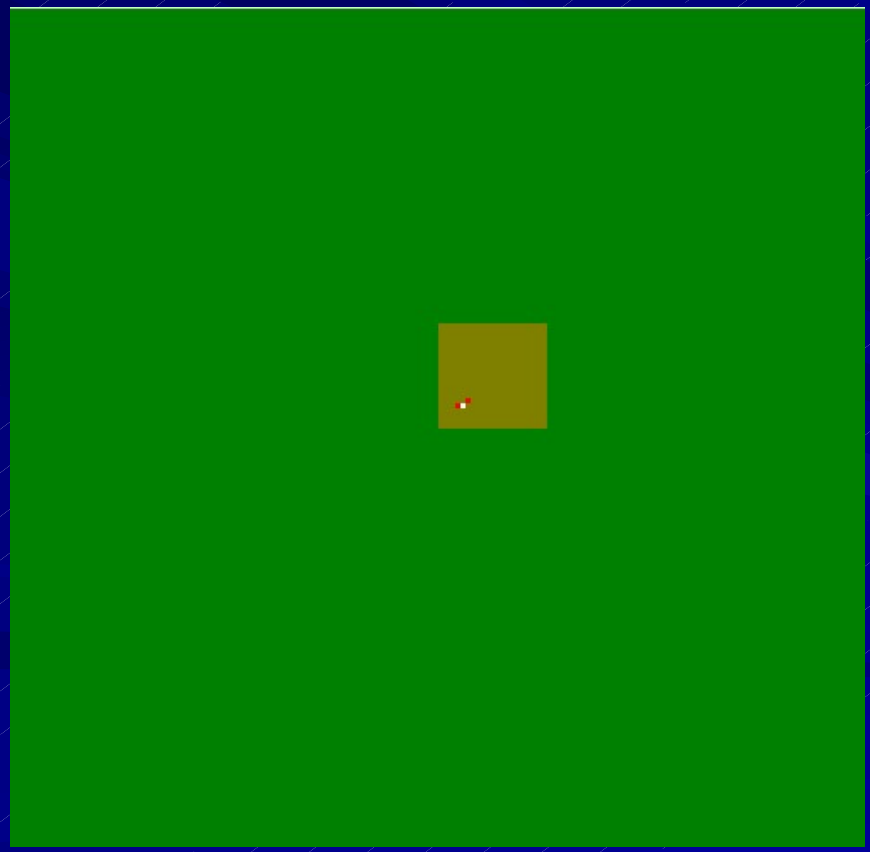
Optimization results

- Convergence



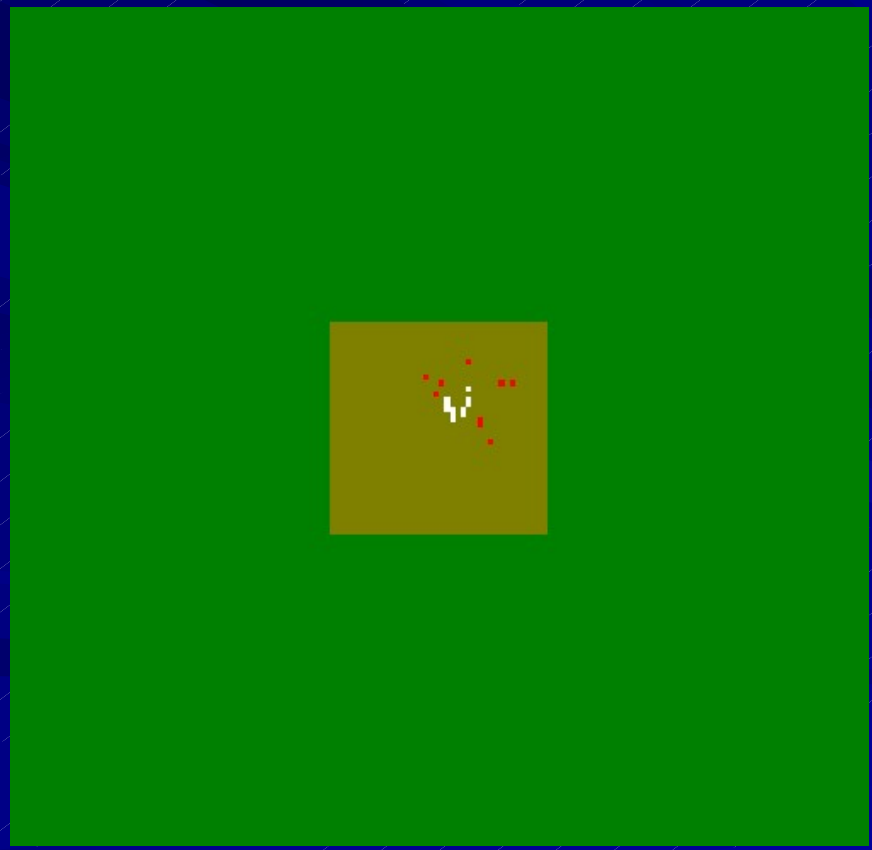
Optimization results

- Immediate detection of first case



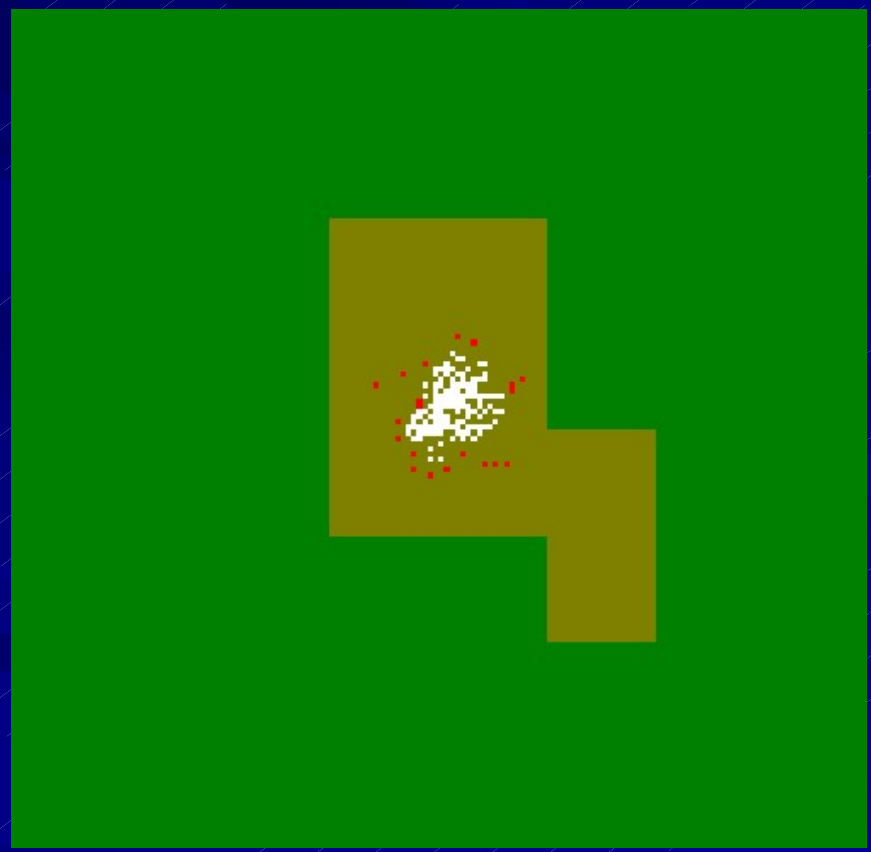
Optimization results

- Detection delay of one year



Optimization results

- Detection delay of two years



Optimization results

- Encircle of Combat?
  - Strategy encircling a rabies focus never occurred
- Vaccination coverage
  - Coverage needed to combat rabies equals ~75%.

    i.e. the same level as during rabies elimination in Europe

Outlook

- Flexibility in designing vaccination areas
  - Smaller grid
- Grid design considers flight lines
- Temporary (episode) rabies cases not allowed
- Threshold analysis
  - Strategies robust to uncertainty with respect to some of the model parameters

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