

# **Spatial Anomalies, Spatial Agents and Spatial Annotation with SAS**

## Agent-based simulation

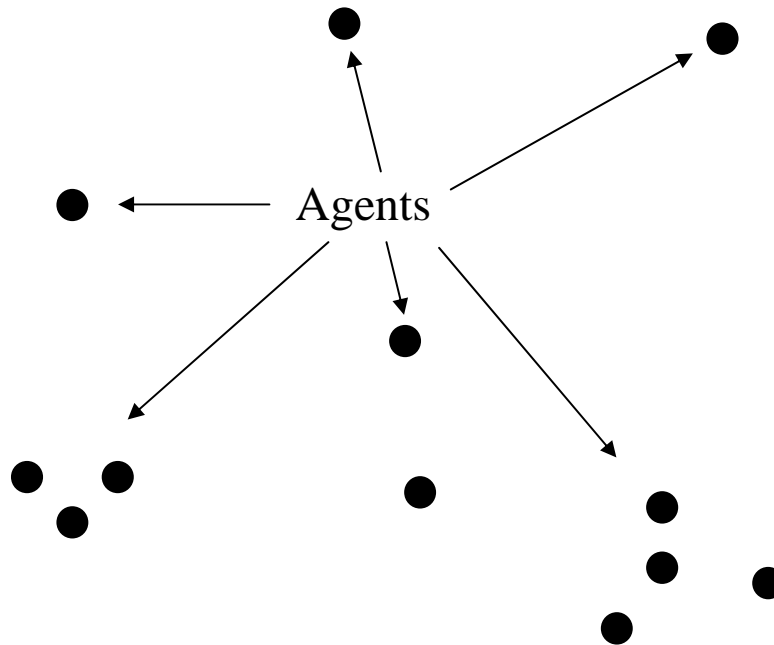
### What is it?

- Simulations in which agents (with attributes and behaviours) interact autonomously
- Useful when trying to understand complex & dynamic systems

### Examples?

- Transportation (e.g., *Transims*-Los Alamos Labs)
- Projecting population structure (e.g., *Modgen*-Statistics Canada)
- Biological warfare (e.g., *Biowar*-University of Pittsburgh & Carnegie Mellon)

## Spatial agent-based simulation



Agent has attributes:

*Location (x,y)*

*Size*

*Attractiveness*

*Ontology (person, family, car)*

Agent has behaviour:

*Interaction with other agents*

*Changing locations*

*Changing behaviour over time*

*Aging*

Agents 'act' autonomously

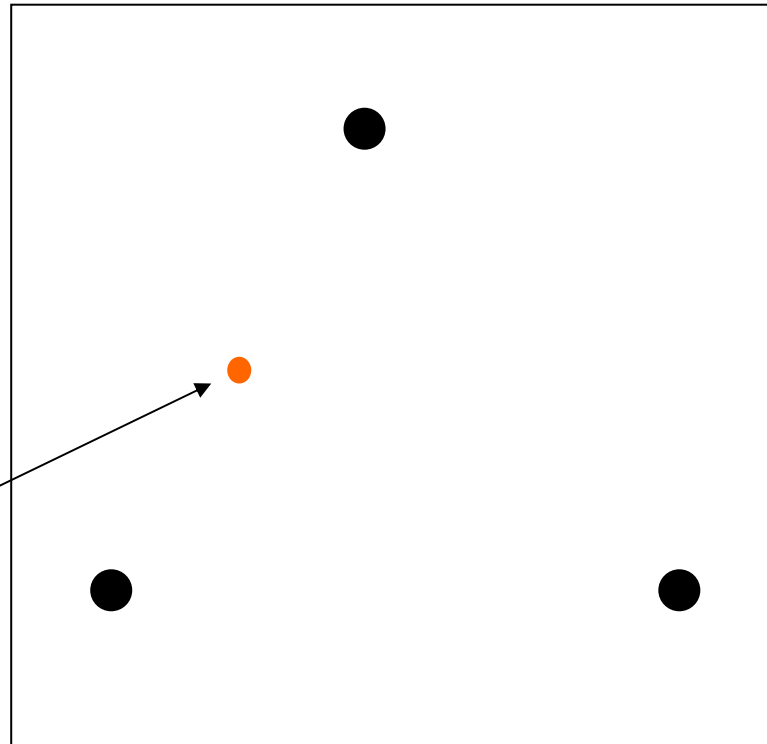
Trivial agent-based model:

Agents with **locations**

Each agent 'interacts' with another agent (chosen at random) and together they produce 'offspring' (a new agent)

The offspring is positioned half-way between the two 'parent' agents

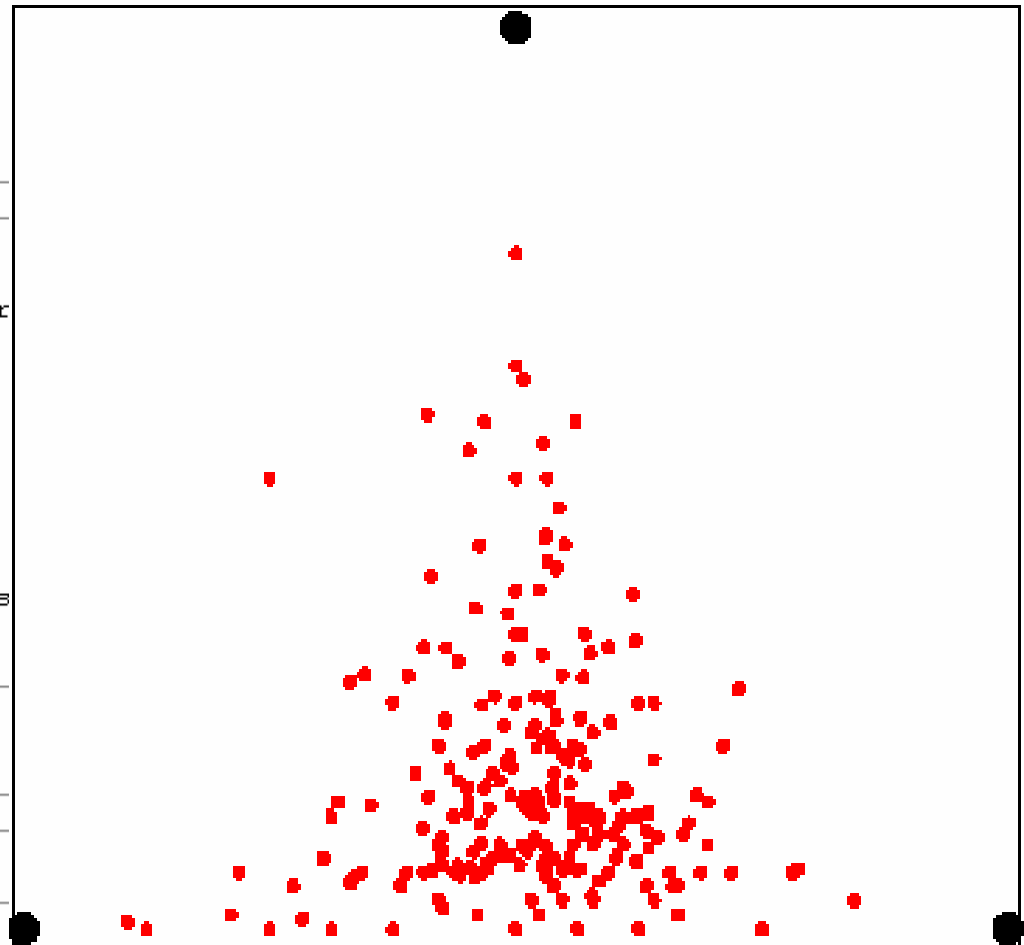
Repeat until bored



```

input x y s;
cards;
3 3 1
1 1 1
1 5 1
;
run;
%let time=100;
%macro rpt;
%do t=1 %to &time;
data agents;set agents;temp=ranuni(0);r
data agents;set agents;cnt+1;run;|
proc sort;by temp;run;
proc sql;
    create table offspring as
    select avg(x) as x, avg(y) as y, 0
    from agents where 1 <= cnt <=2;
quit;
data agents;set agents(keep=x y s) offs
%end;
%mend;
run;
%rpt;
run;
proc sort data=agents;by s;run;
symbol1 height=.5 value=dot c=red;
symbol2 height=1.5 value=dot c=black;
proc gplot data=agents;
    plot x*y=s/nolegend noaxis;
run;

```



## Agent-based simulation for immunization planning

### Problem:

- Immunization to control infection
- Immunization works best if uptake is high *and* residual susceptibility is well-mixed in the population
- Some communities/groups are under-immunized
  - Ethical/philosophical objections
    - Religious/cultural communities
  - Practical issues
    - Distance, transportation, SES, family structure, etc.
- Goal: use agent based simulations to examine possible immunization strategies to manage the ‘clustering’ of susceptibility

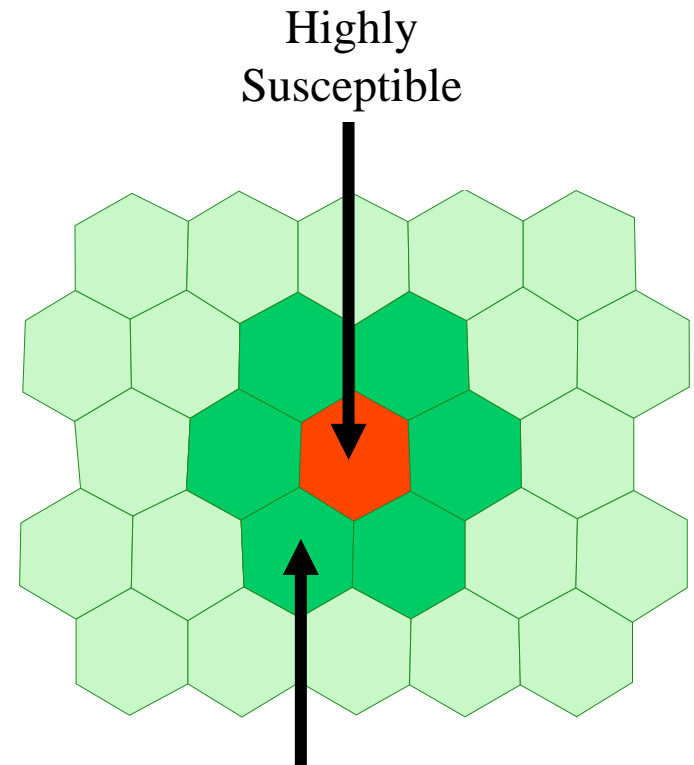
### **‘Offensive containment’**

Form a ‘ring’ of high immunity around an infected area

Analogous to fire control

### ***Prospective offensive containment***

Form a ‘ring’ of immunity around the susceptible (low resistance/no immunization) areas



Focus immunization efforts here to prevent spread elsewhere

## Agent-based simulation using SAS

### General strategy:

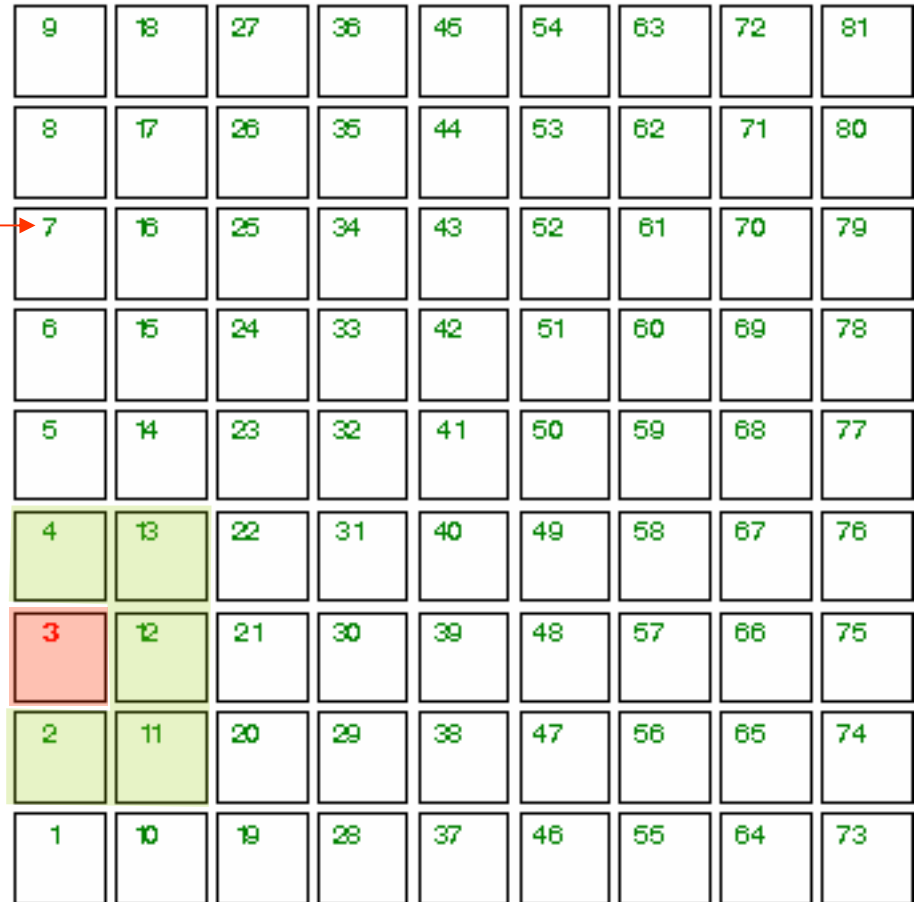
- 1) Create agents
  - Location, immunization status, infectious status
- 2) Create a behaviour model
  - Agents interact with each other according to a probabilistic spatial interaction model (probability of interaction is a function of distance)
- 3) Resolve the simulation at  $t$ 
  - Determine who interacts with who, who gets sick, who becomes resistant, etc.
  - Repeat step 3 until equilibrium or until a specified length of time passes (ideally, iterate *within* a [data step](#))

- Simplify output to square lattice (each cell has a # of agents)

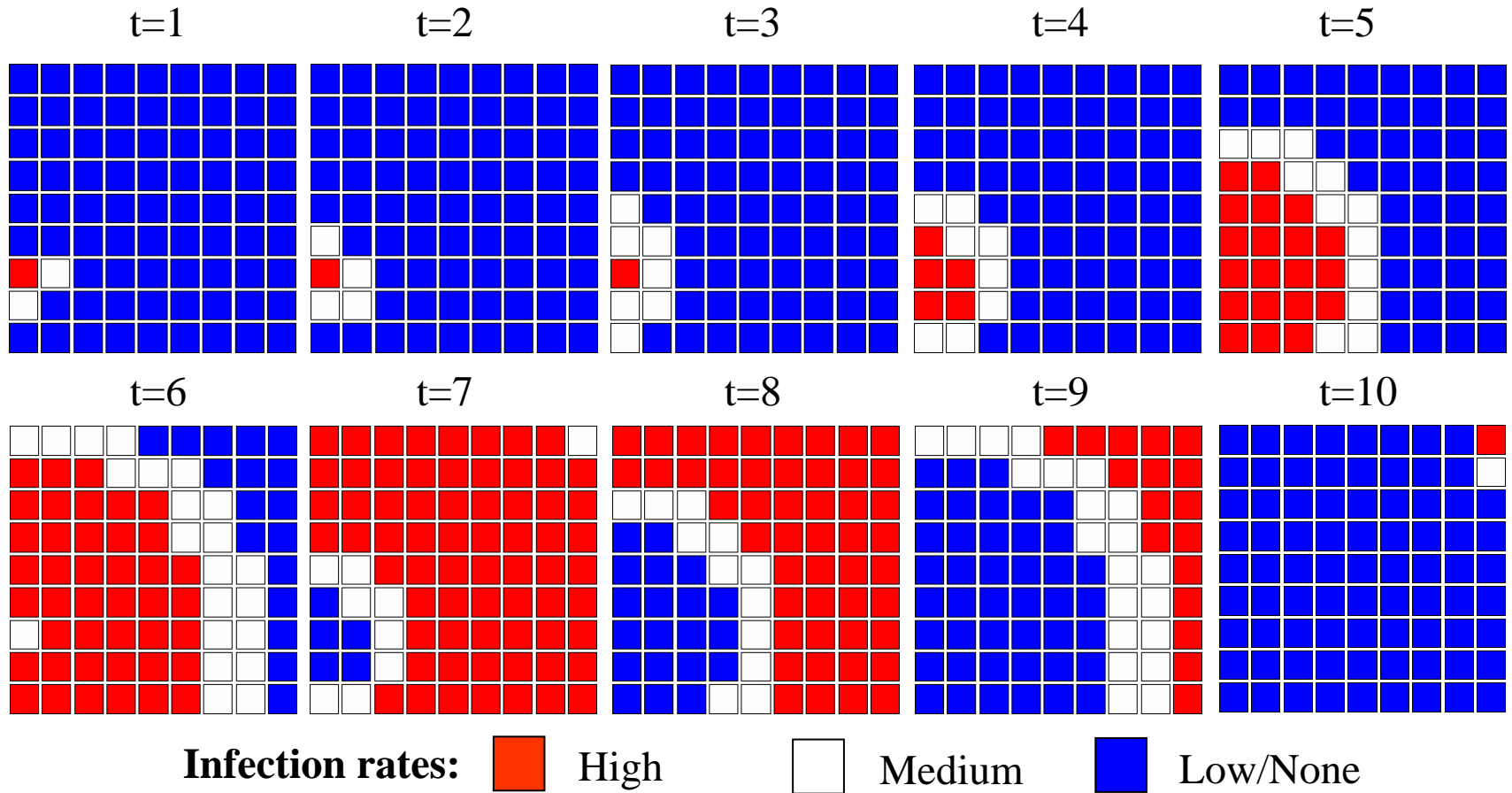
Use `proc gmap` to render the lattice, use `annotate` for numbers

Identify a 'rogue' region where the outbreak starts & where immunization coverage is low

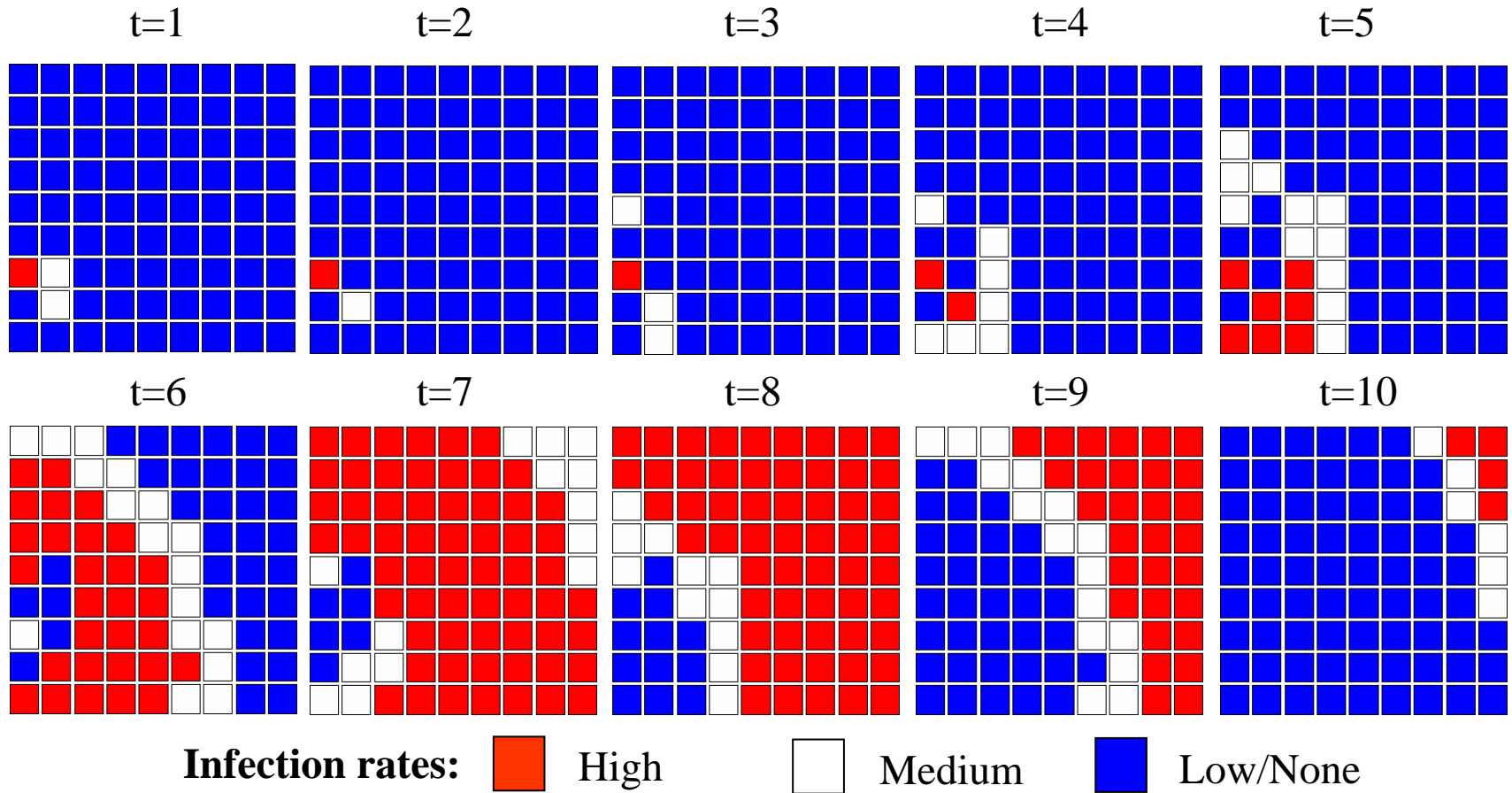
Identify a 'containment' region with high immunization coverage



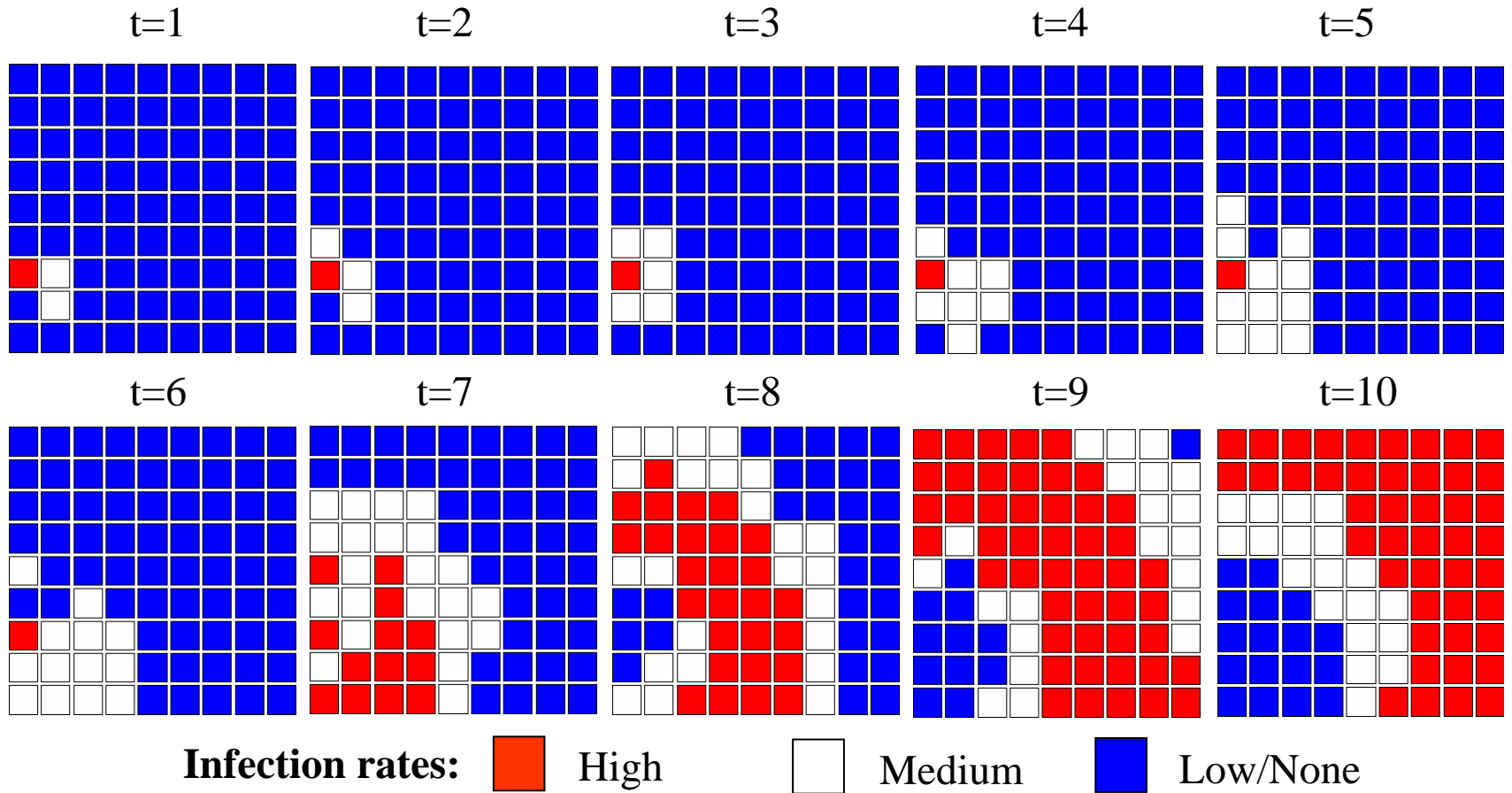
# Scenario 1: no immunization anywhere



Scenario 2: offensive containment (containment areas have 75% immunity, rogue 0%, other=0%)



Scenario 3: offensive containment (containment areas have 75% immunity, rogue=0%, other=50%)

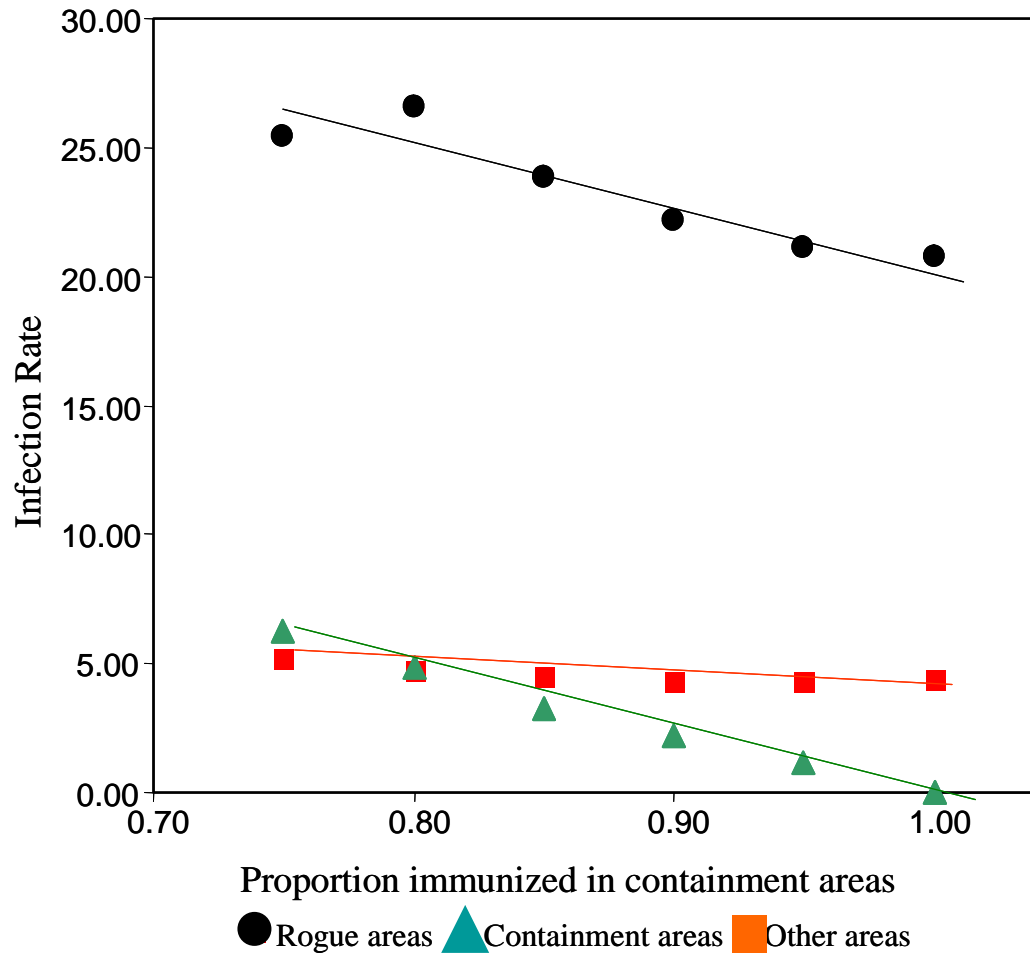


Agent-based simulation using SAS

Simulation based on synthetic landscape

Conclusions/Results:

- 1) Containment can slow the spread of disease to general population...



## Agent-based simulation using SAS

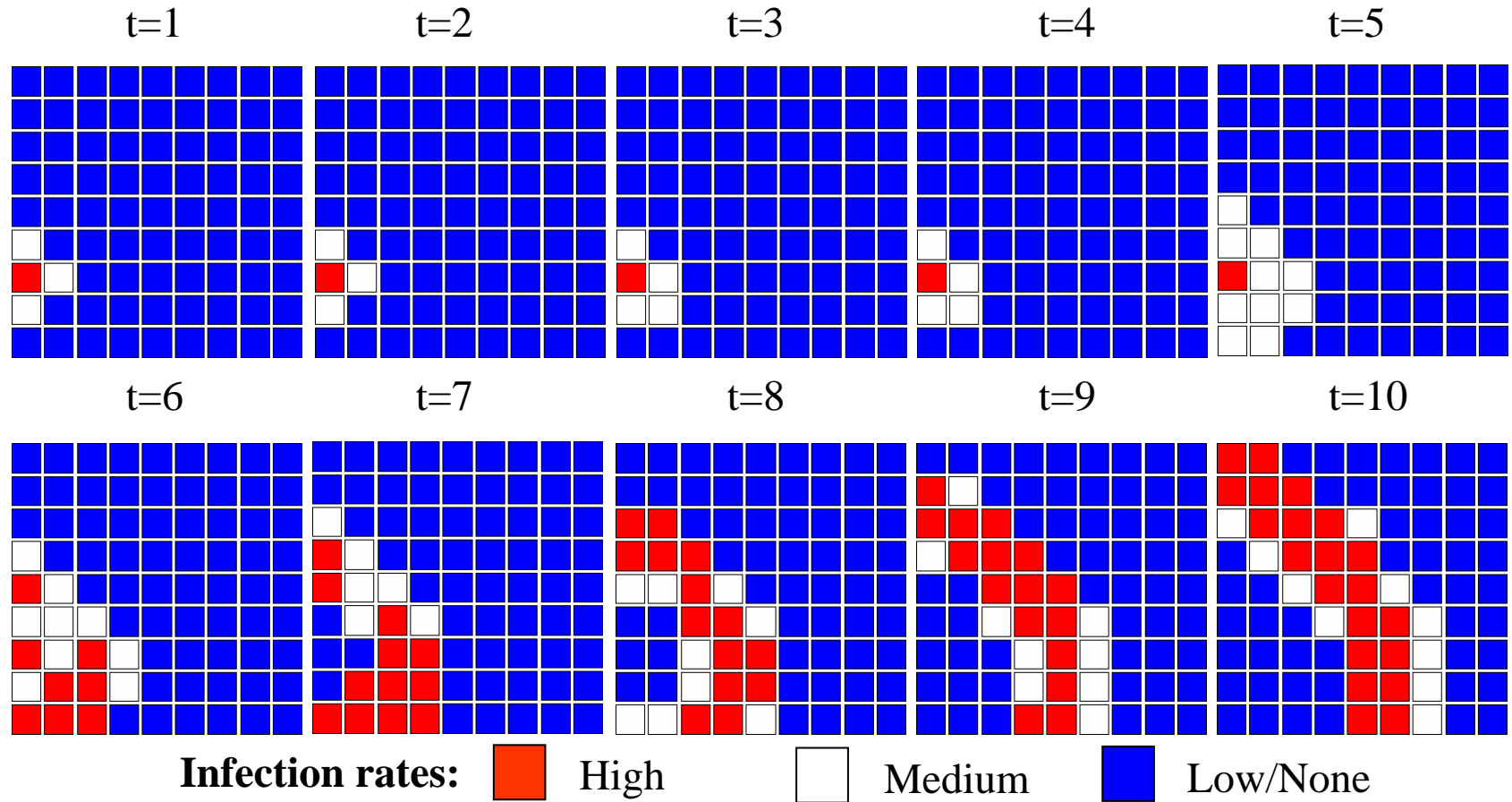
Simulation based on synthetic landscape

Conclusions/Results:

- 1) Containment can slow the spread of disease to general population
- 2) Pace of diffusion is dependent on the spatial interaction model
  - Agents may be ‘adventurous’ (and travel great distances to interact)
  - Agents may be ‘parochial’ and stay in and around home

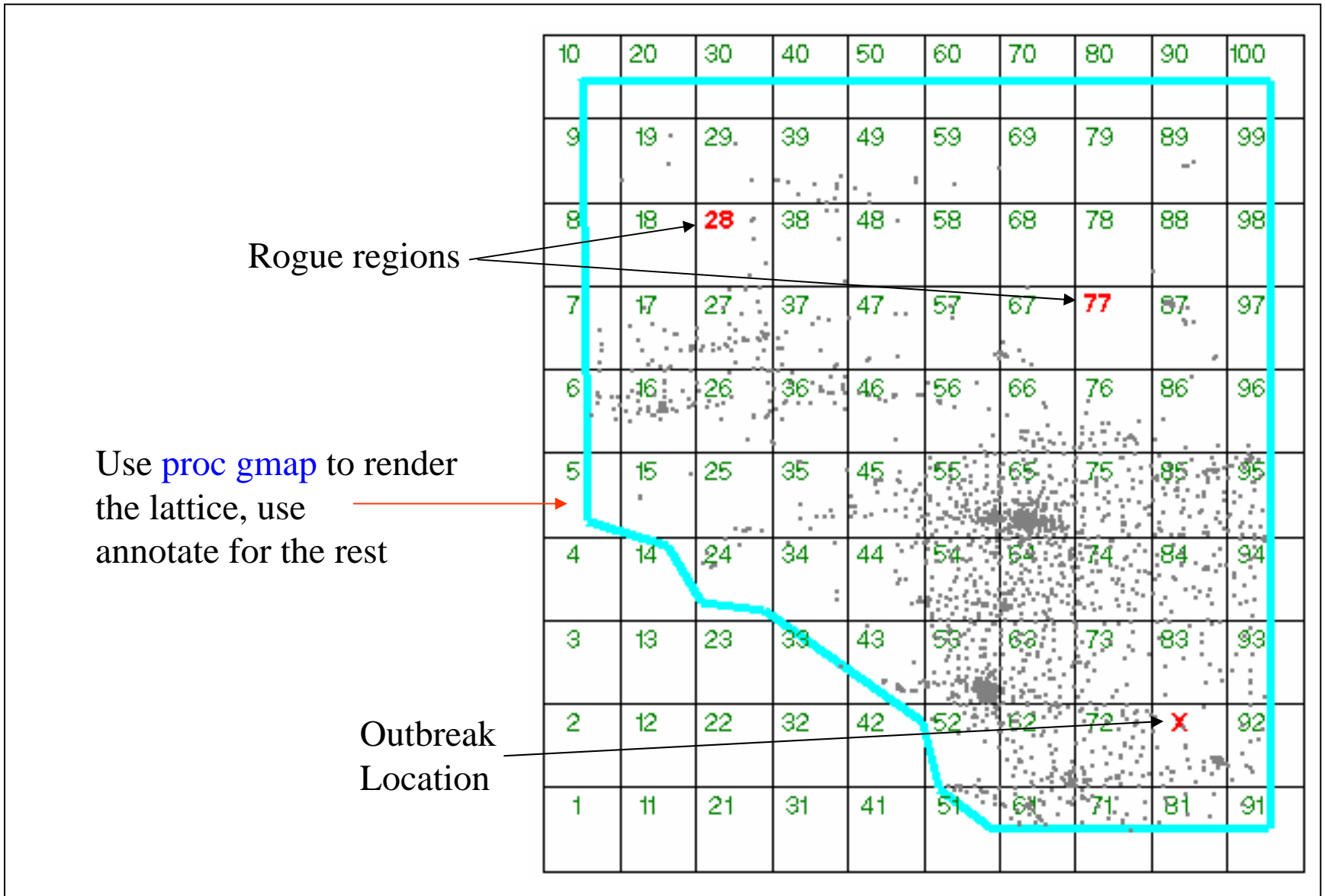
Scenario 4: offensive containment (surrounding areas have 75% immunity, rogue=0%, other=50%)

With a parochial spatial interaction model

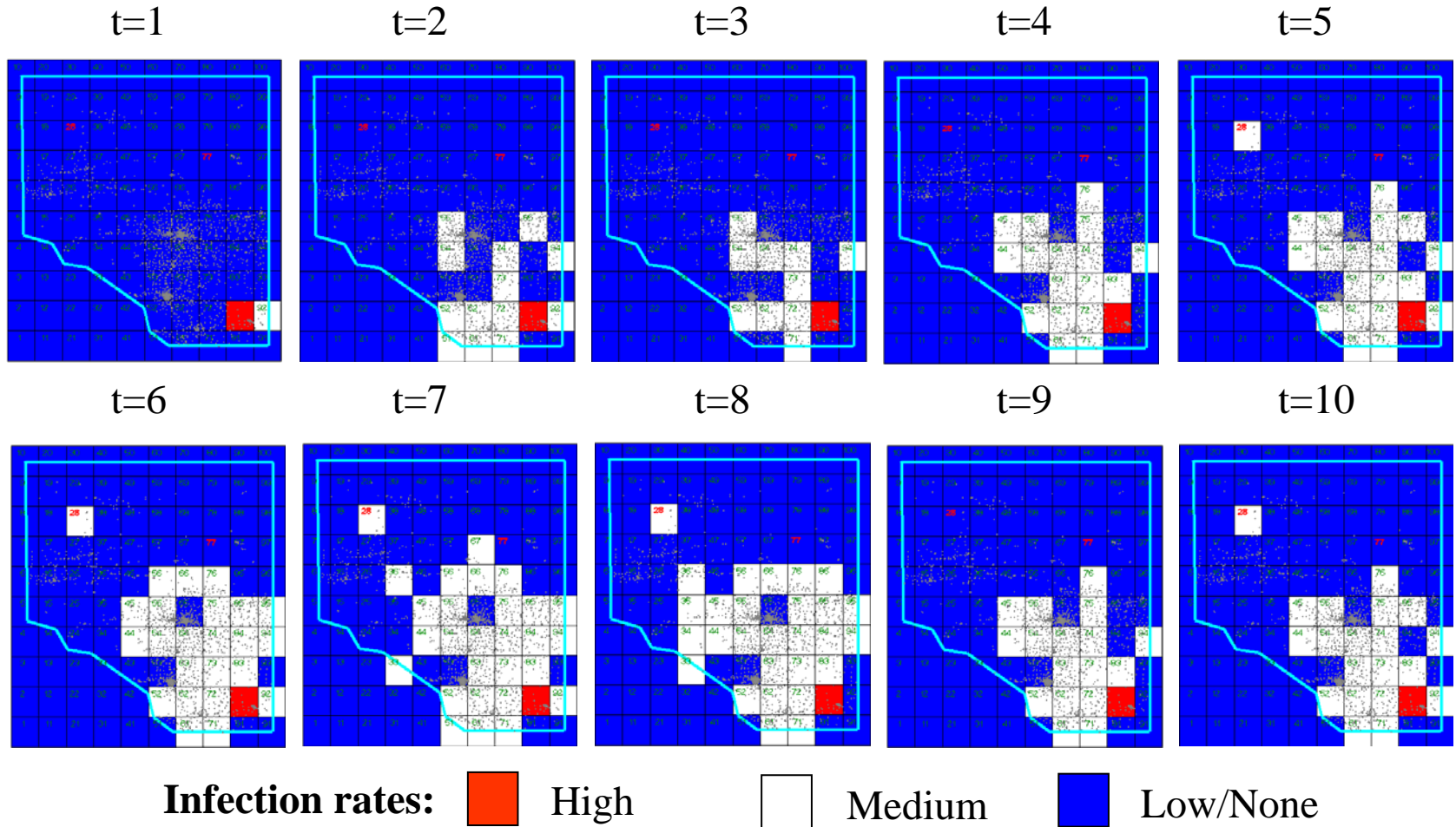


## Agent-based simulation using SAS: Simulations based on the Alberta population

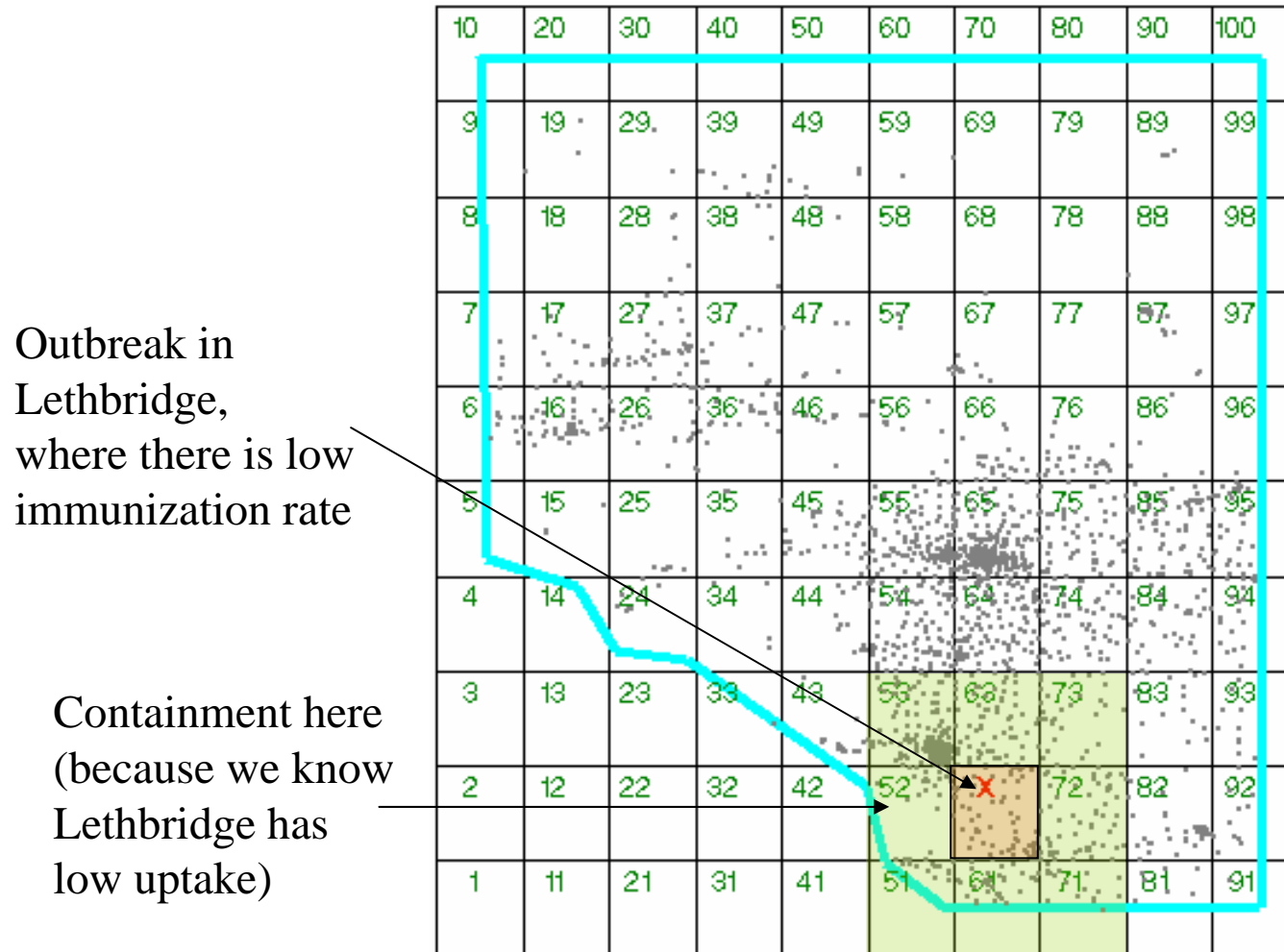
- Agents are the population (Total Census 2001)
- Locations are postal codes
- For the sake of speed, one-way spatial interaction model (only how the infected interact with the susceptible)
- Create a map (with `proc gmap`) and use *annotate* in SAS



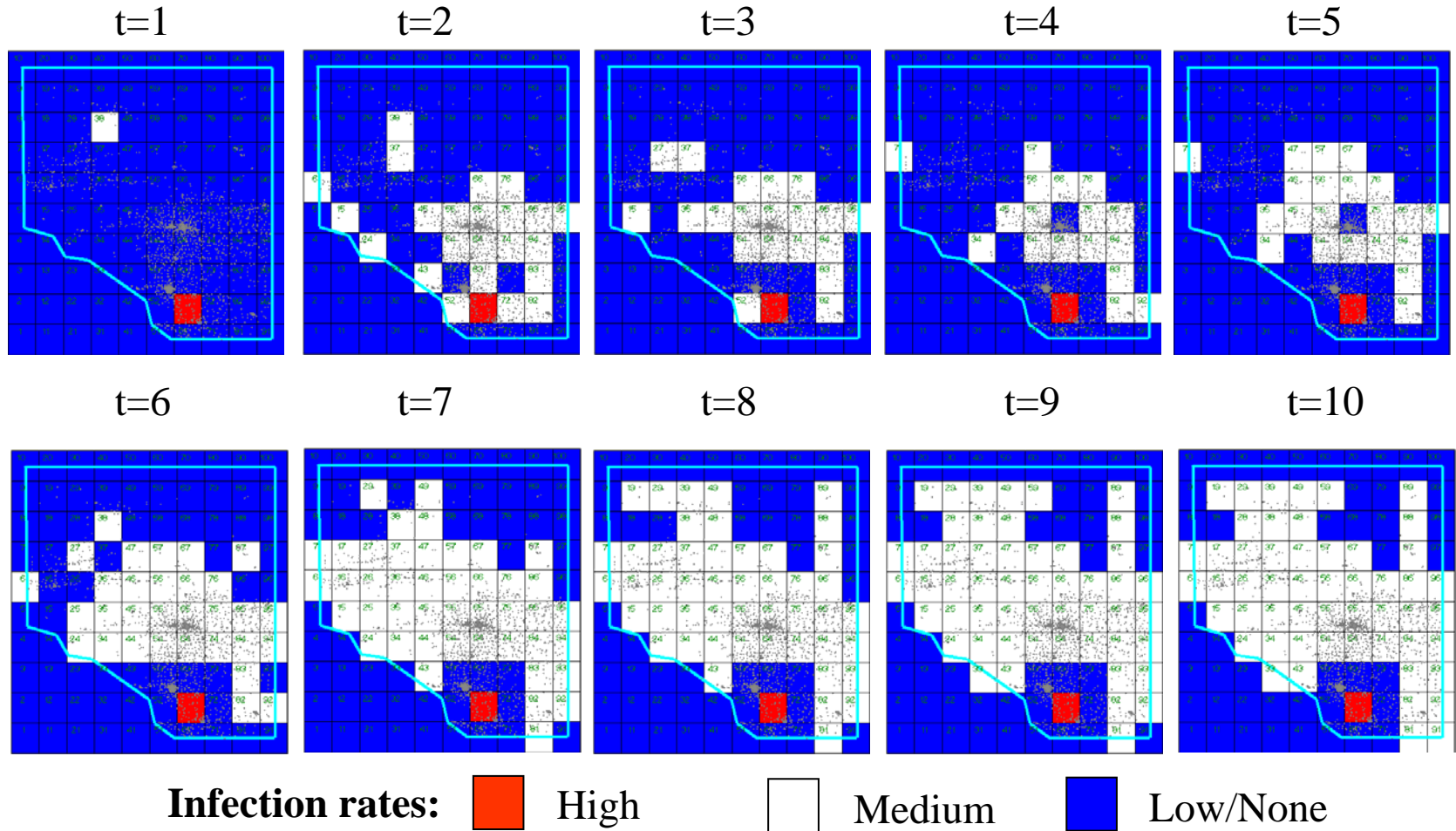
Scenario 1: Urban immunization is high (Edmonton & Calgary 90%, rogue 0%, other 75%)



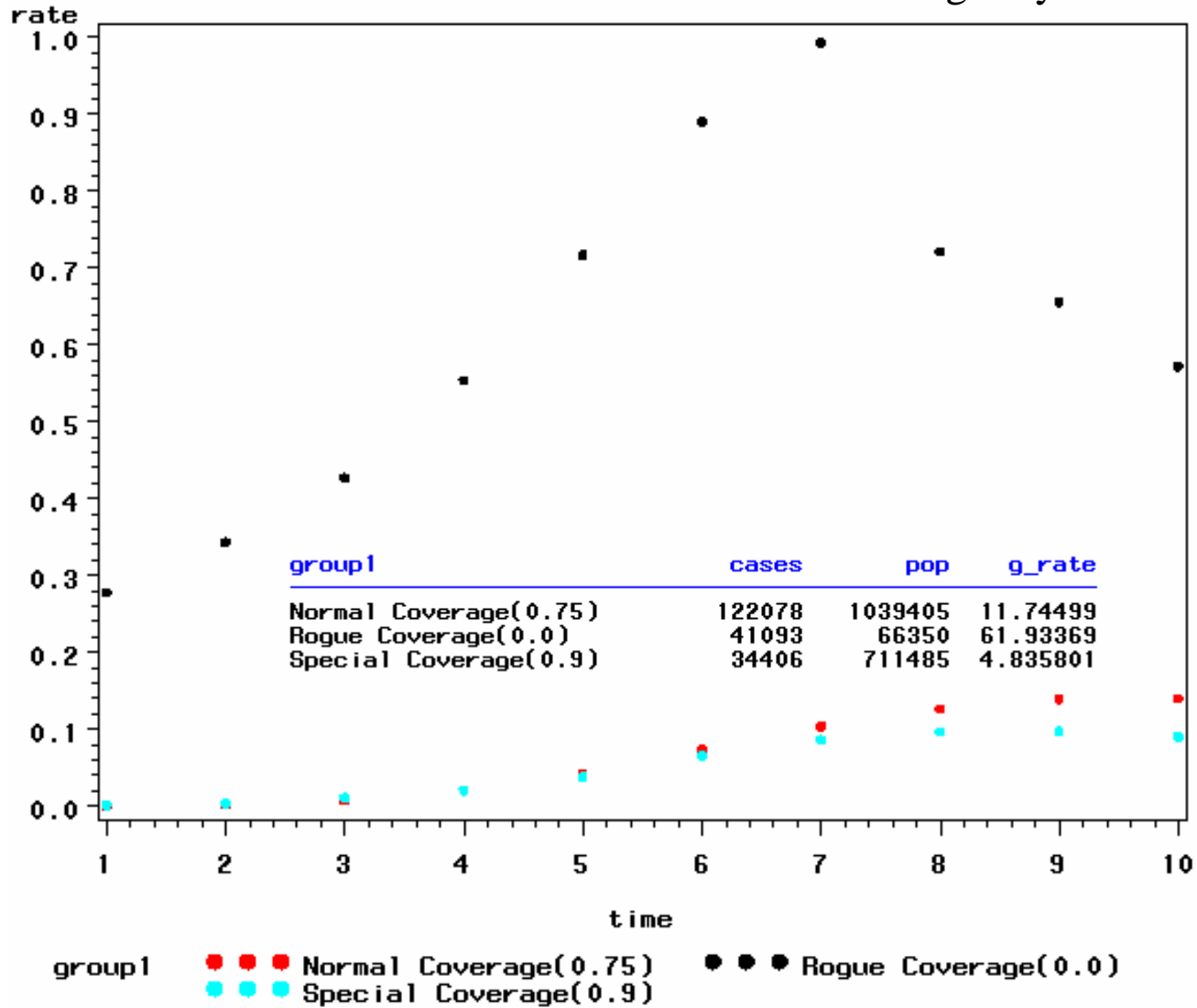
## Scenario 2: Offensive containment (Outbreak in Lethbridge, containment @ 90%, other 75%)



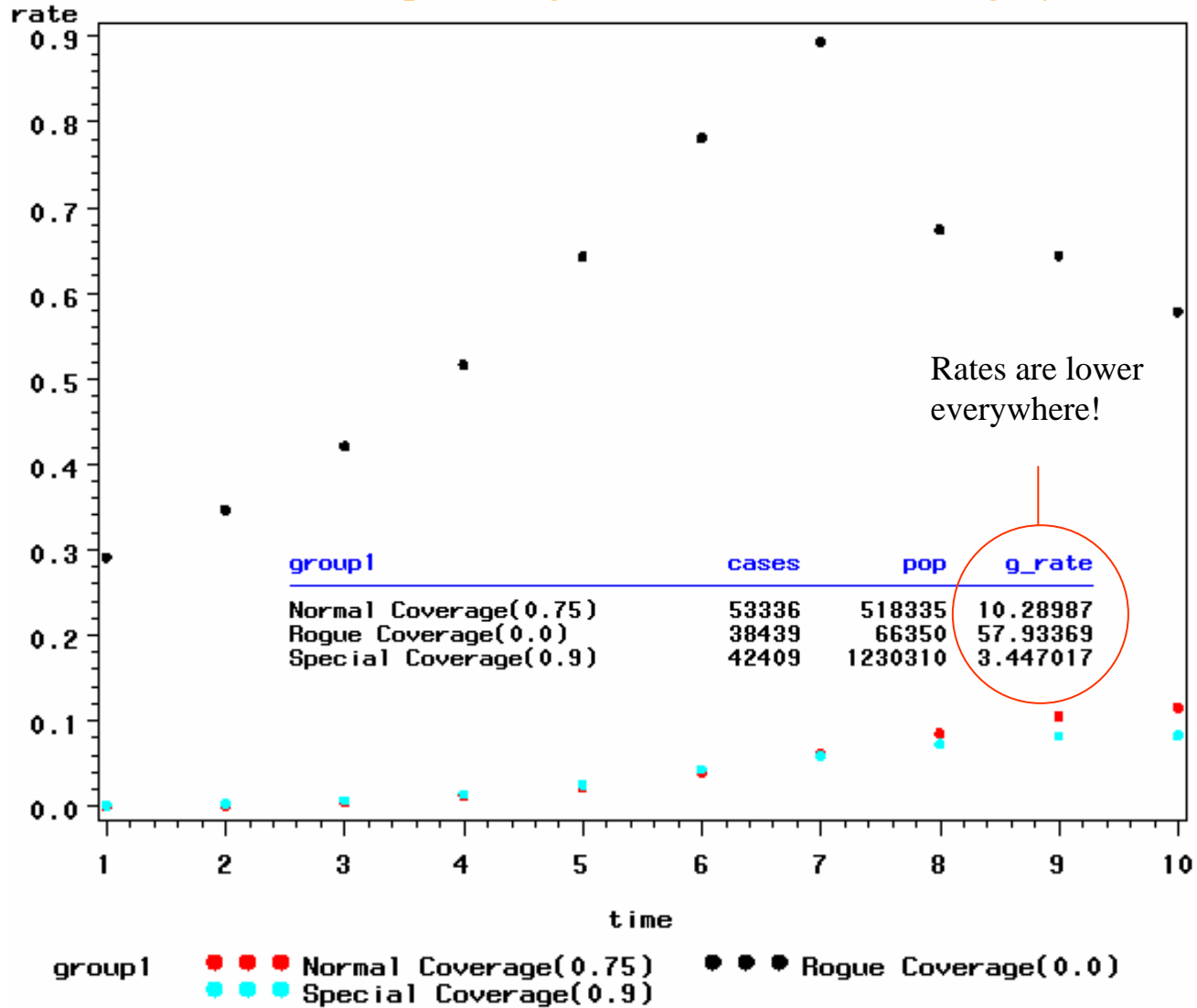
## Scenario 2: Offensive containment (Outbreak in Lethbridge, containment @ 90%, other 75%)



# Infection rates over time: containment ring only



## Containment equals ring AND Edmonton & Calgary



## Agent-based simulation using SAS

Alberta

Conclusions/Results:

1) Model makes intuitive sense

- Containment (through high immunization uptake) can slow the spread of infection
- Pace of diffusion is dependent on the spatial interaction model, so uptake in highly populated areas is particularly important for maximizing vaccine efficacy

2) SAS can be a good prototyping environment for simple agent-based simulations

3) With `proc gmap` and `annotate`, colourful maps with overlaying objects/labels are easy!