Rabies in Raccoons -and - Improving CPR

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Outline

- Models
- Improving CPR, Cardiopulmonary Resuscitation
- Rabies in Raccoons

Funding

CPR work - funding initially by ORNL seed money grant

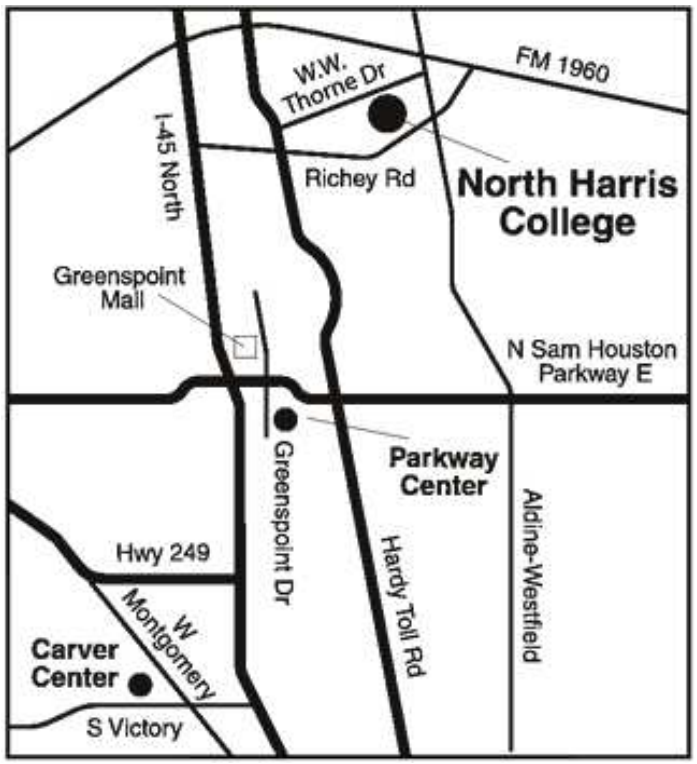
Rabies work - National Science Foundation

and University of Tennessee

Models

WHAT is a MODEL?

A model is like a map — it represents part of reality but not all of it!



Tools?

MODELS!!

When do you use a simple model in your everyday life to make a decision?

models?

Maybe you use a model at the grocery store in choosing a checkout line.

Use mathematical models for research work

- Drug treatment strategies for HIV/AIDS
- Control practices for tuberculosis epidemics
- Drug treatments for leukemia
- Management strategies for Lyme disease
- West Nile virus –just starting
- Improving CPR, Cardiopulmonary Resuscitation
- Rabies in raccoons

Mathematical Models

Inputs to a system of equations are adjusted until the desired goal output is obtained. (A 'system' has several equations.)

Equations involve rates of change and interaction and movement terms among the components of the system.

Improving Cardiopulmonary Resuscitation

Each year, more than 250,000 people die from cardiac arrest in the USA alone.

Despite widespread use of cardiopulmonary resuscitation, the survival of patients recovering from cardiac arrest remains poor.

The rate of survival for CPR performed out of the hospital is 3%, while for patients who have cardiac arrest in the hospital, the rate of survival is 10-15%.

Goal

The goal is to improve traditional CPR technique by using optimal control methods.

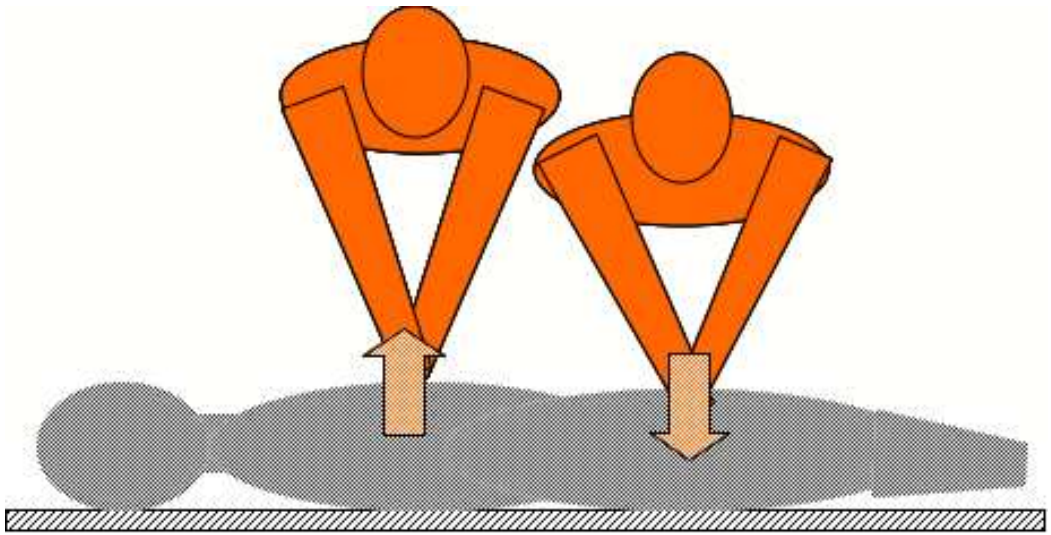
The standard and various alternative CPR techniques such as interposed abdominal compression IAC, and Lifestick CPR have been represented in various models.

There are devices that can facilitate decompression. (create negative pressures)

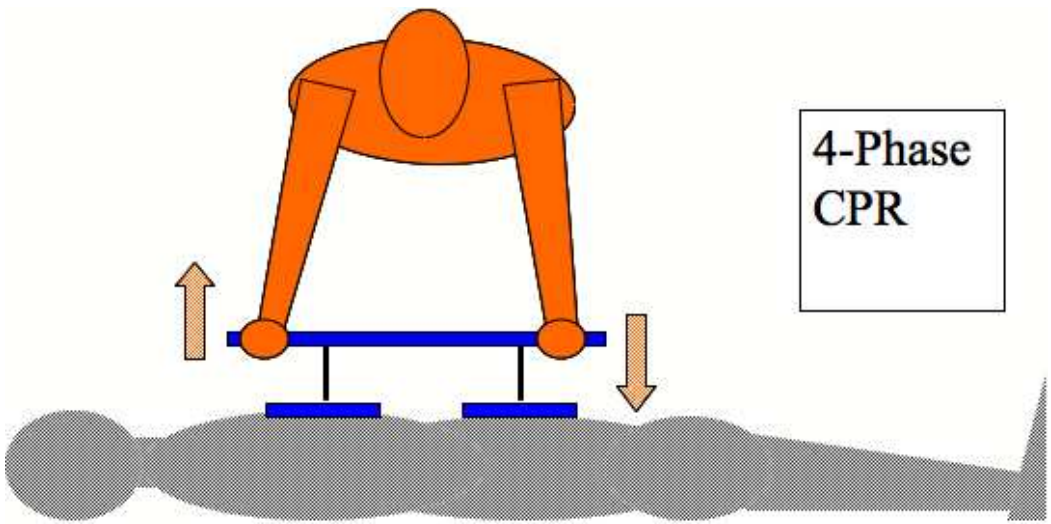
We consider a model for CPR allowing chest and abdomen compression and decompression.

Design optimal PATTERN of compression/decompression!

Interposed Abdomen Compression



Lifestick



Model by Babbs

We apply the optimal control strategy for improving resuscitation rates to a circulation model developed by Babbs. (model -discrete in time, with seven compartments)

In his model, heart and blood vessels are represented as resistance-capacitive networks, pressures in the chest and in the vascular components as voltages, blood flow as electric current, and valves .

Reference: Babbs, Circulation 1999.

Heart Diagram

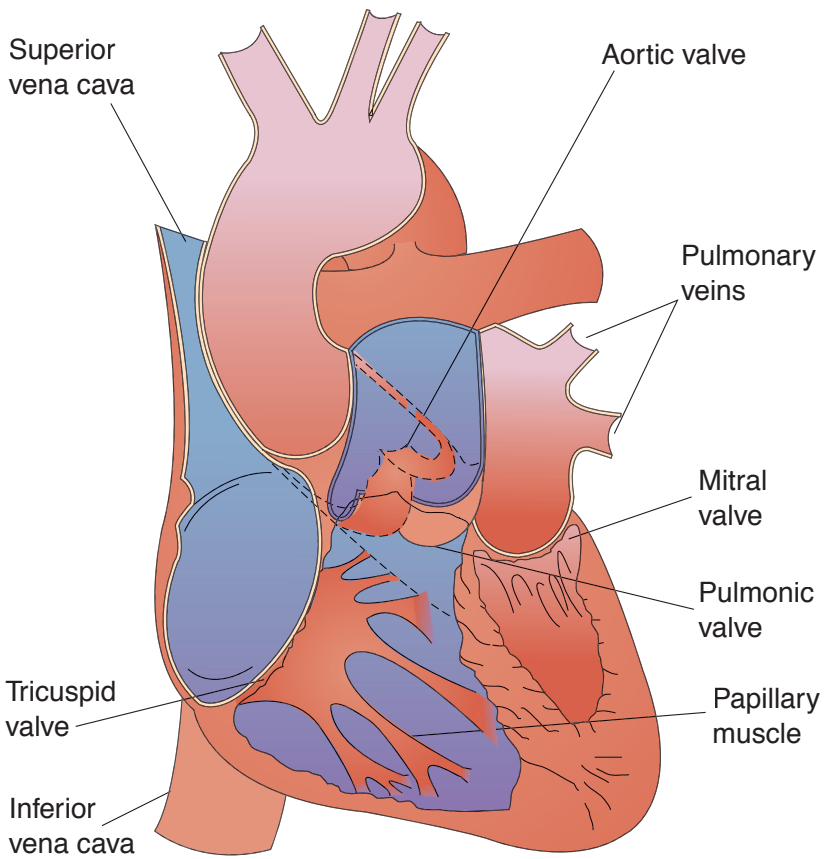
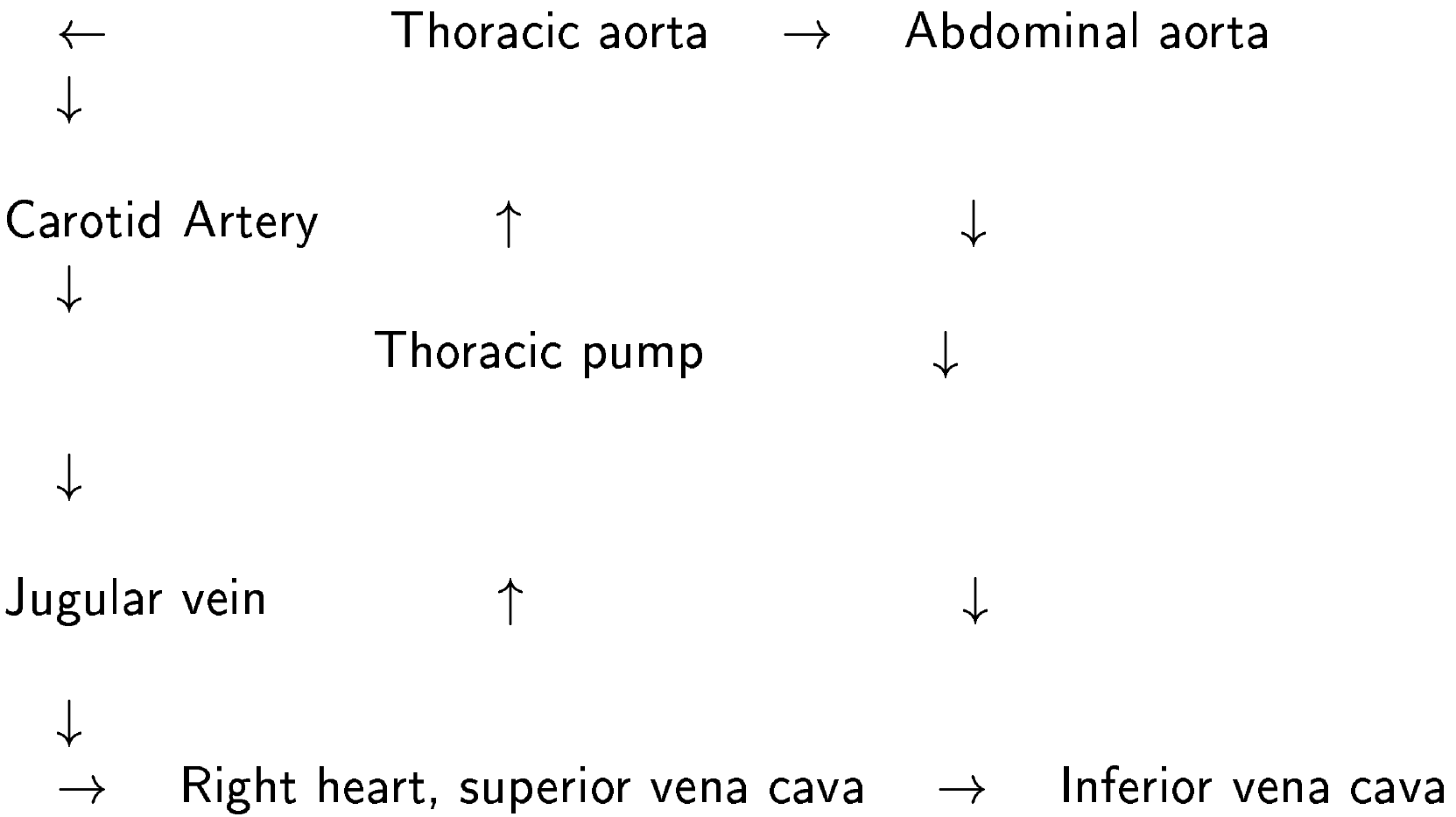


Figure 23-11 Valvular structures of the heart. The atrioventricular valves are in an open position, and the semilunar valves are closed. There are no valves to control the flow of blood at the inflow channels (*i.e.*, vena cava and pulmonary veins) to the heart.

Diagram of Circulation Model



Seven Components in the Model

P_1 pressure in abdominal aorta
P_2 pressure in inferior vena aorta
P_3 pressure in carotid artery
P_4 pressure in jugular vein
P_5 pressure in thoracic aorta
P_6 pressure in rt. heart, superior vena cava
P_7 pressure in thoracic pump and left heart.

Goal for this model

Design compression/depression patterns for chest and abdomen pressures

To increase pressure differences across thoracic aorta and right heart

SPP - Systemic Perfussion Pressure

Pressure Profiles

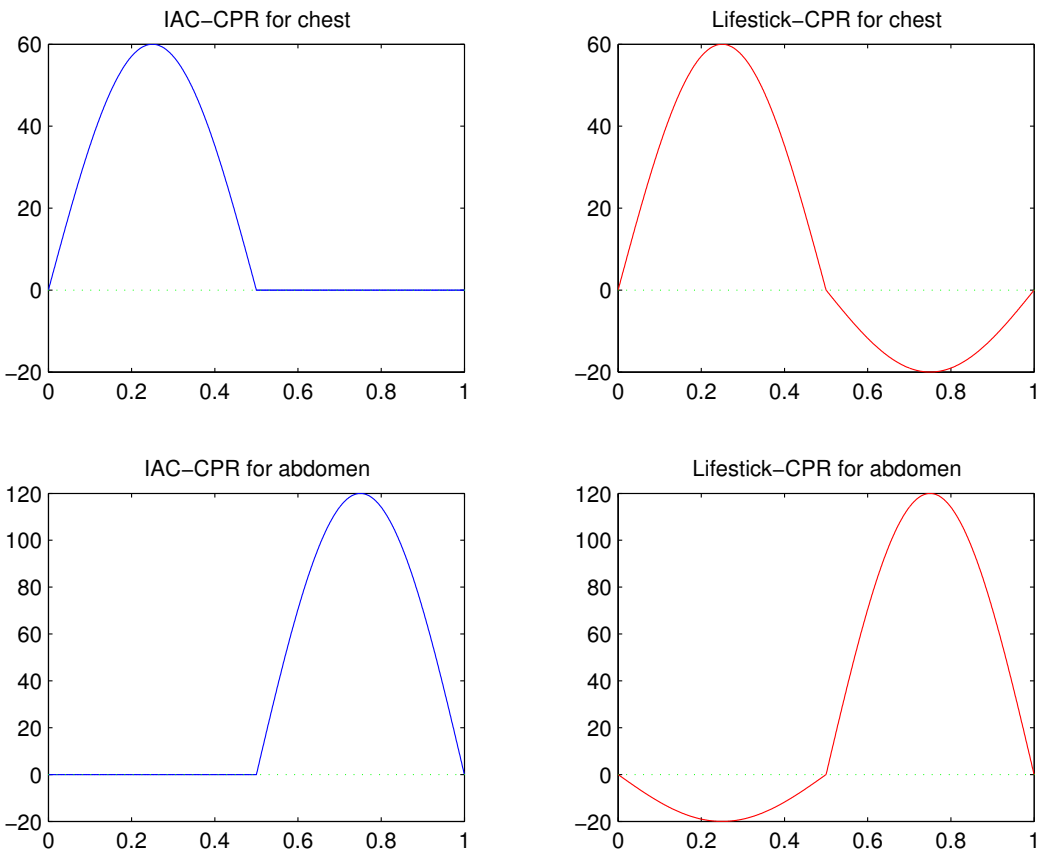
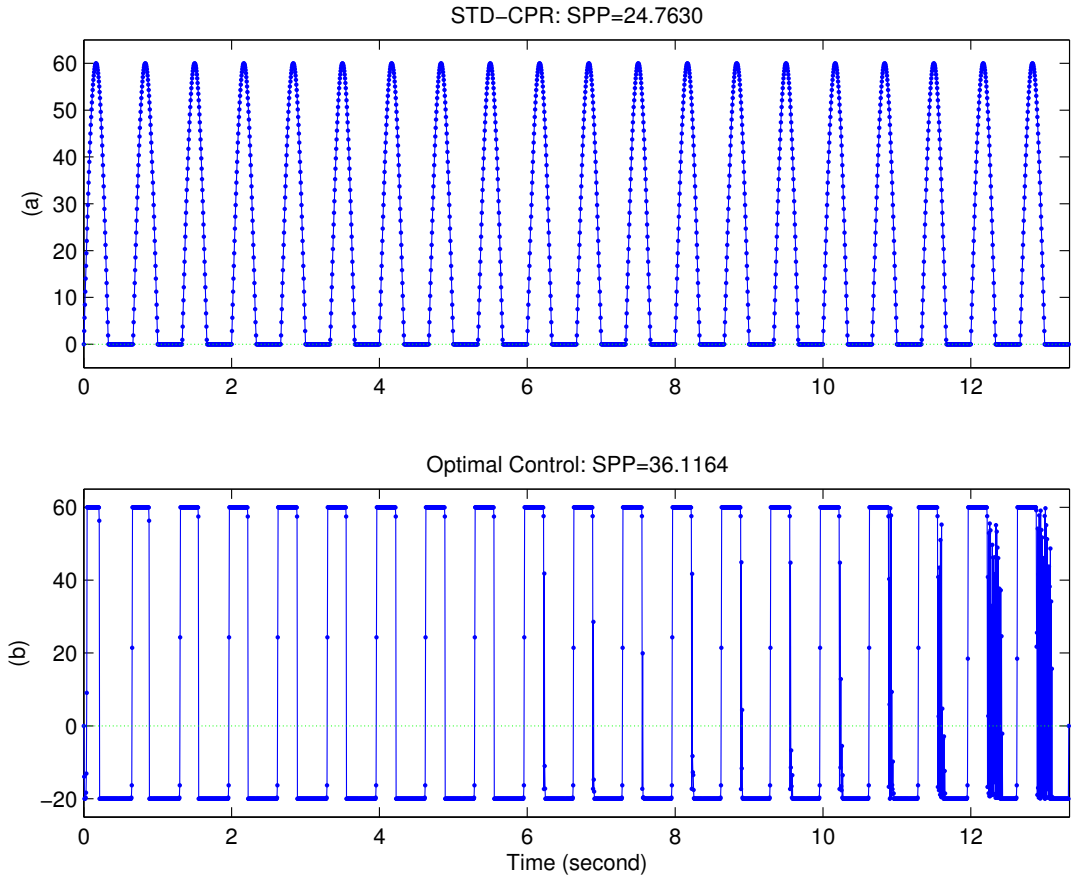


Figure: Each waveform represents one cycle.

Optimal Control on Chest only and Standard Profiles



OC Profiles

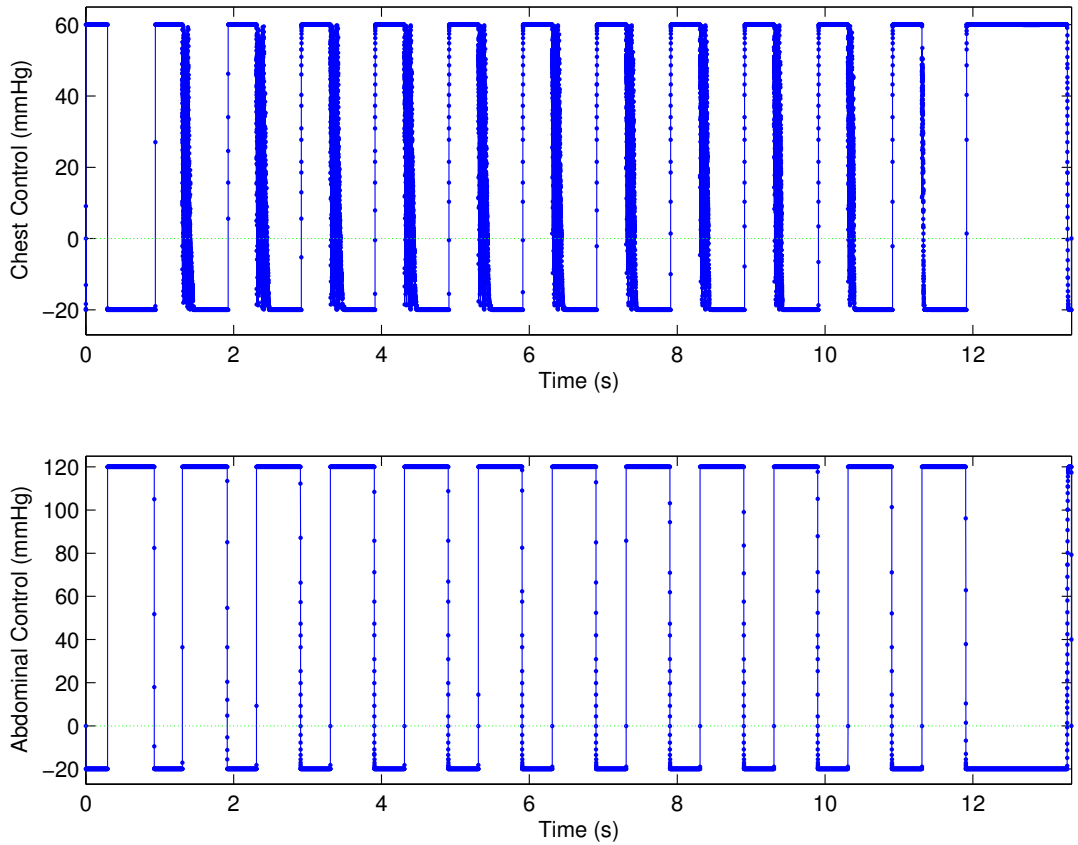


Figure: The controlled chest and abdominal pressure using Lifestick

Concluding Remarks about CPR

This procedure with RAPID compression and decompression cycles has recently been recommended by several medical groups. (use a device)

We can increase the pressure difference across the thoracic aorta and the right heart by about 25 percent.

publications: Academic Emergency Medicine Journal 2006, Math. Methods and Models in Applied Sciences 2005

Rabies in Raccoons

- Rabies is a common viral disease.
- Transmission is through the bite of an infected animal.
- Raccoons are the primary terrestrial vector for rabies in the eastern US.
- Vaccine is distributed through food baits. (preventative)
- Medical and Economic Problem -death to humans and livestock and COSTS

Reported Cases of Raccoon Rabies, 2001

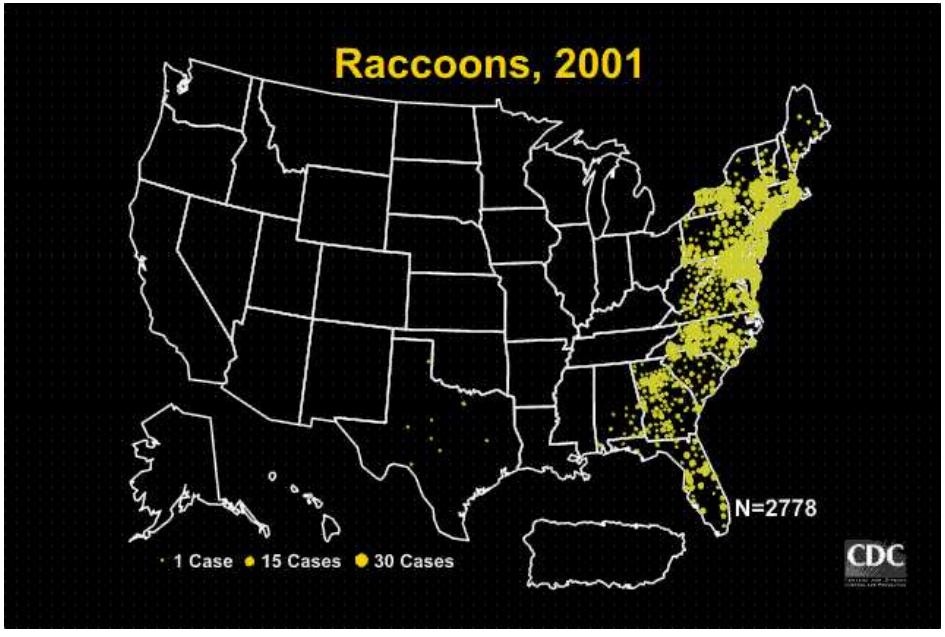
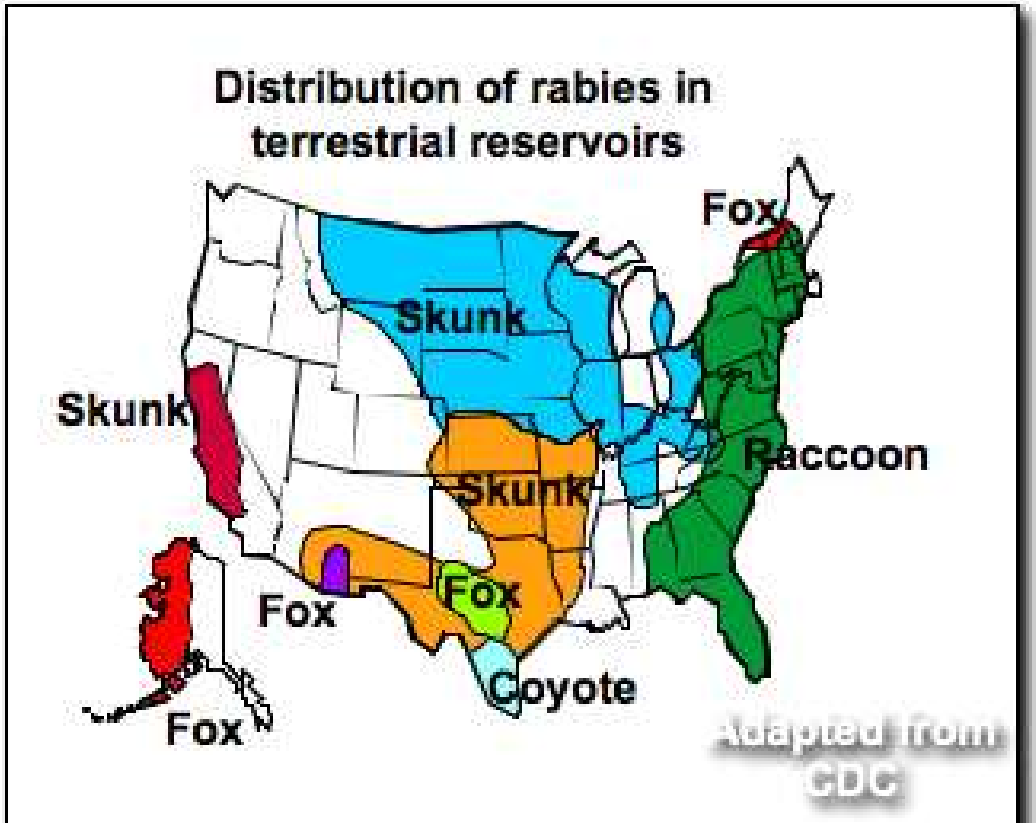


Figure: Reported Cases of Raccoon Rabies, 2001, *http://www.cdc.gov*

Distribution of Rabies



Rabies in Bats

Not covering this topic today

Two local experts - Gary McCracken and Tom Hallam, Ecology and Evolutonary Biology Department

Distribution of Vaccine to Raccoons

Costs and Treatment associated with Rabies in USA

30,000 persons/year given rabies post exposure prophylaxis at a cost of $30 million

Treatment - one dose of rabies immune globulin (injected near the site of the bite)

and- five doses of vaccine over 28 days (injected into upper arm)

Symptoms - flu-like at first, about 10-60 days after exposure, later delirium, coma, disruption of nervous system

Overall costs

Vaccination and prevention cost $300 million/year

More nationwise

About 39 percent of the reported rabies cases nationwide in 2005 came from raccoons.

In recent years, 8 million baits were distributed over 15 Eastern states.

In Tennessee

For the last six years, the Tennessee borders with Georgia, Virginia, and North Carolina have been baited with rabies vaccine.

In fall 2007, packets will be dropped from low-flying airplanes over a 22-county area in Tennessee.

Deaths due to Rabies

Bites by rabid dogs are the source of 40,000 human rabies death each year globally.

There are about 3 deaths per year in USA due to rabies.

Most of those deaths in USA are attributed to unrecognized exposures to rabid bats.

There was one case in USA of a girl (infected with rabies from a bat, not discovered until symptoms occurred) who was treated successfully by putting her into a coma. 2004

Goal

Develop models and numerical results to investigate distribution patterns for vaccine baits, as it impacts the spread of rabies among raccoons.

Reduce the chance of rabies spread while keeping the costs of vaccine distribution as low as possible.

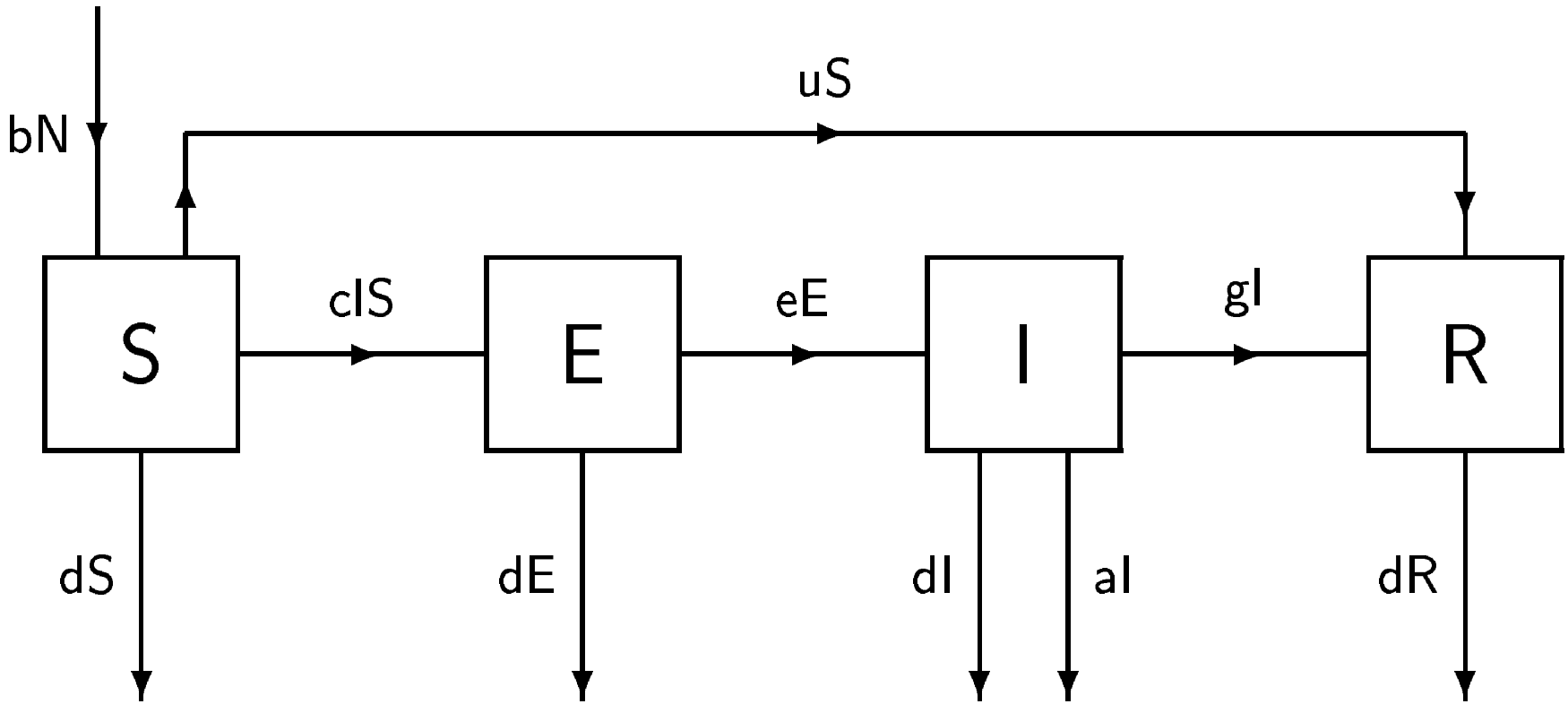
More Precise Goal

Minimize the number of infected raccoons while taking into account limited amount of funding for the distribution of vaccine baits.

Notation

- S = susceptibles
- E= exposed
- I = infecteds
- R = immune
- V = vaccine
- control u, input of vaccine baits

Model -control moves raccoons from Susceptible to Immune



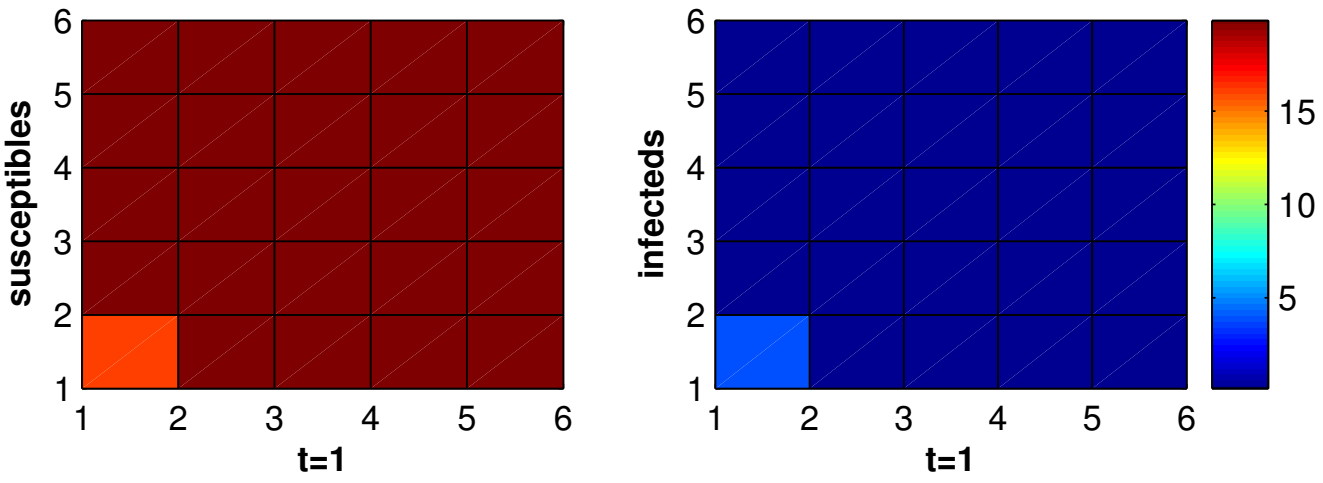
Numerical Example

Using a square grid with 25 boxes, we do the math analysis followed by the numerical solution.

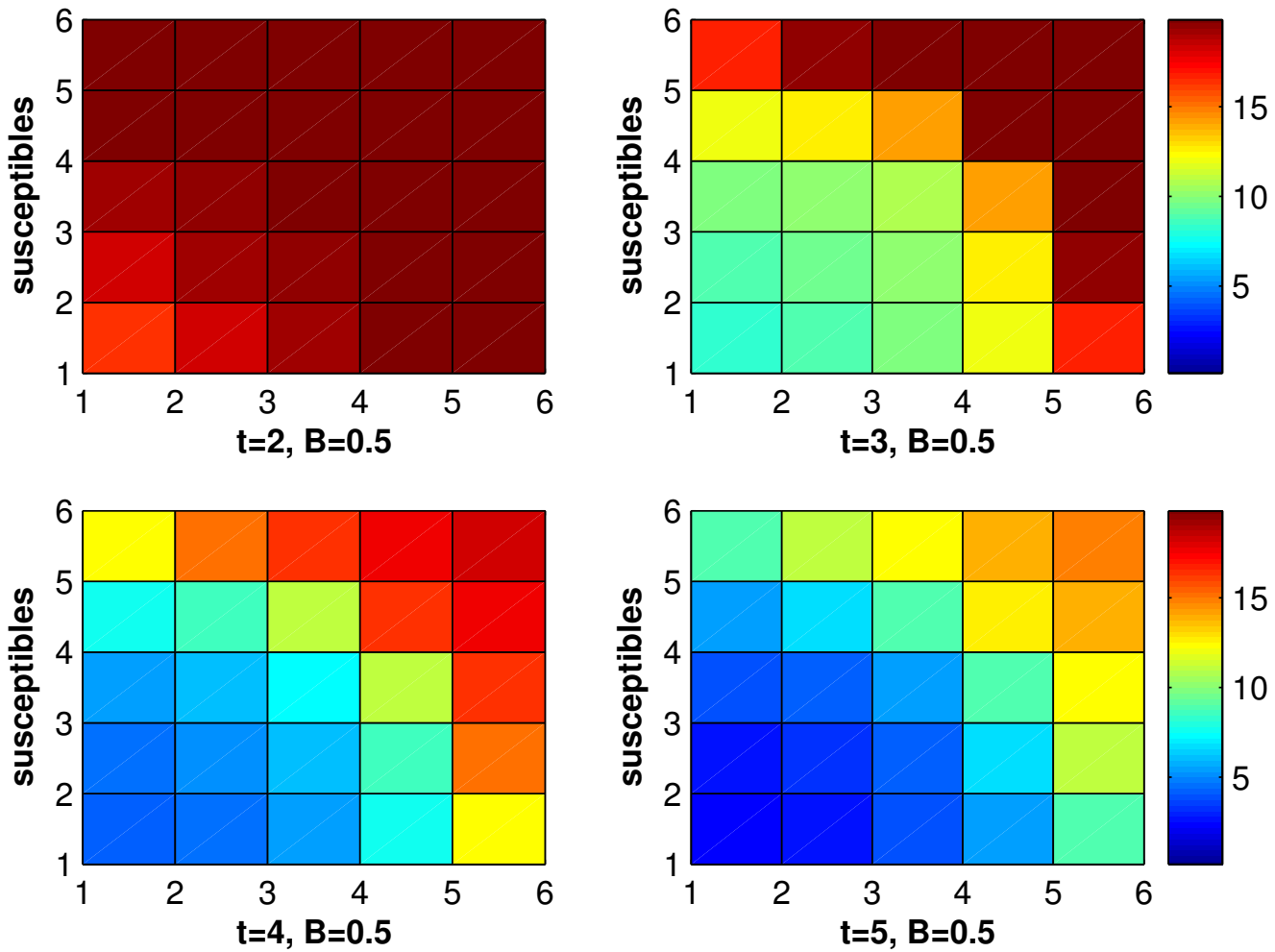
In each box, 8 equations are solved at each time step. Four equations for S, I, R, and V and four equations for the optimizing procedure.

To get convergence to optimal bait distribution, about 100 iterations are completed.

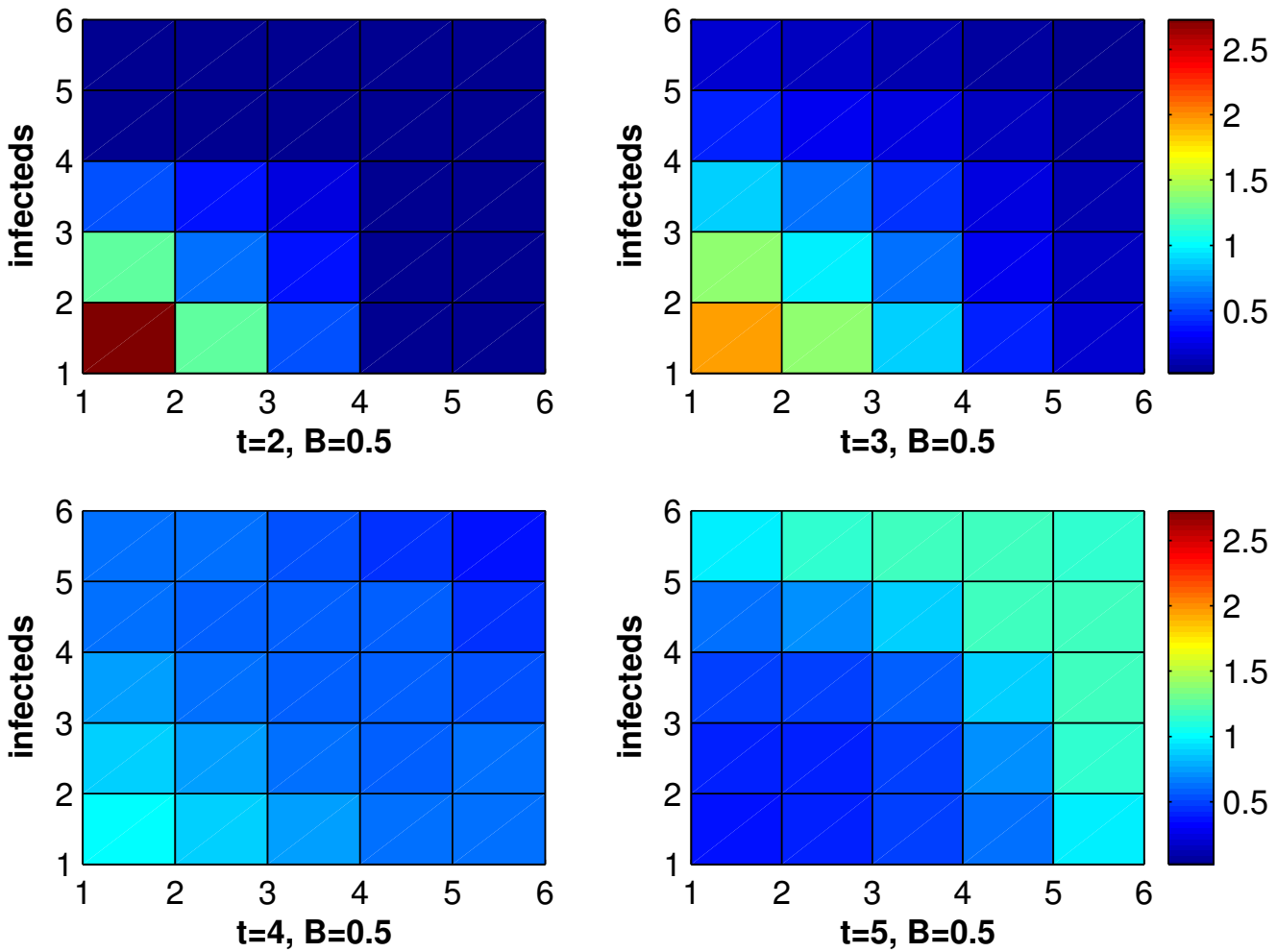
Disease Starts From the Corner: Initial Distribution



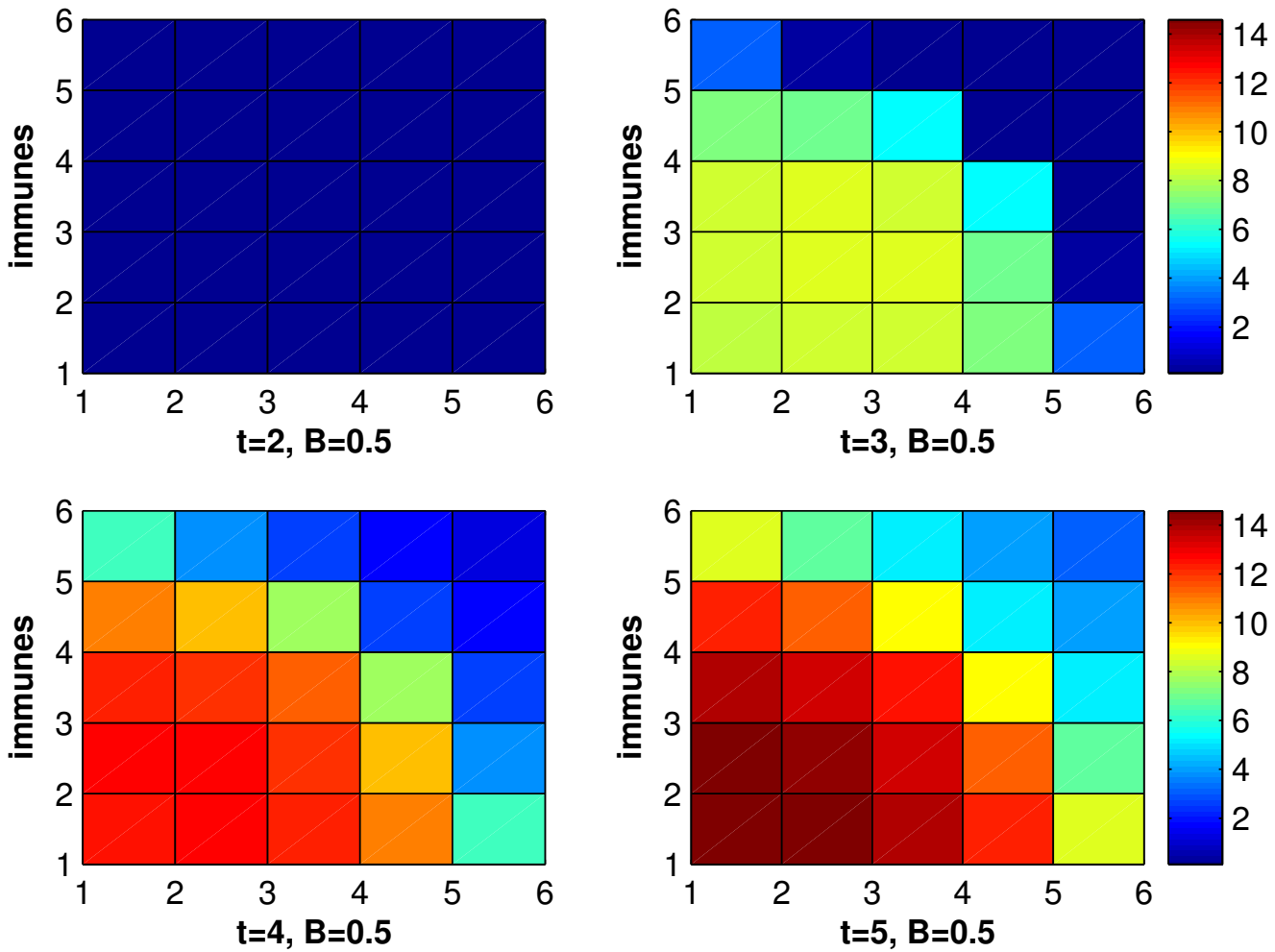
Susceptibles, with control



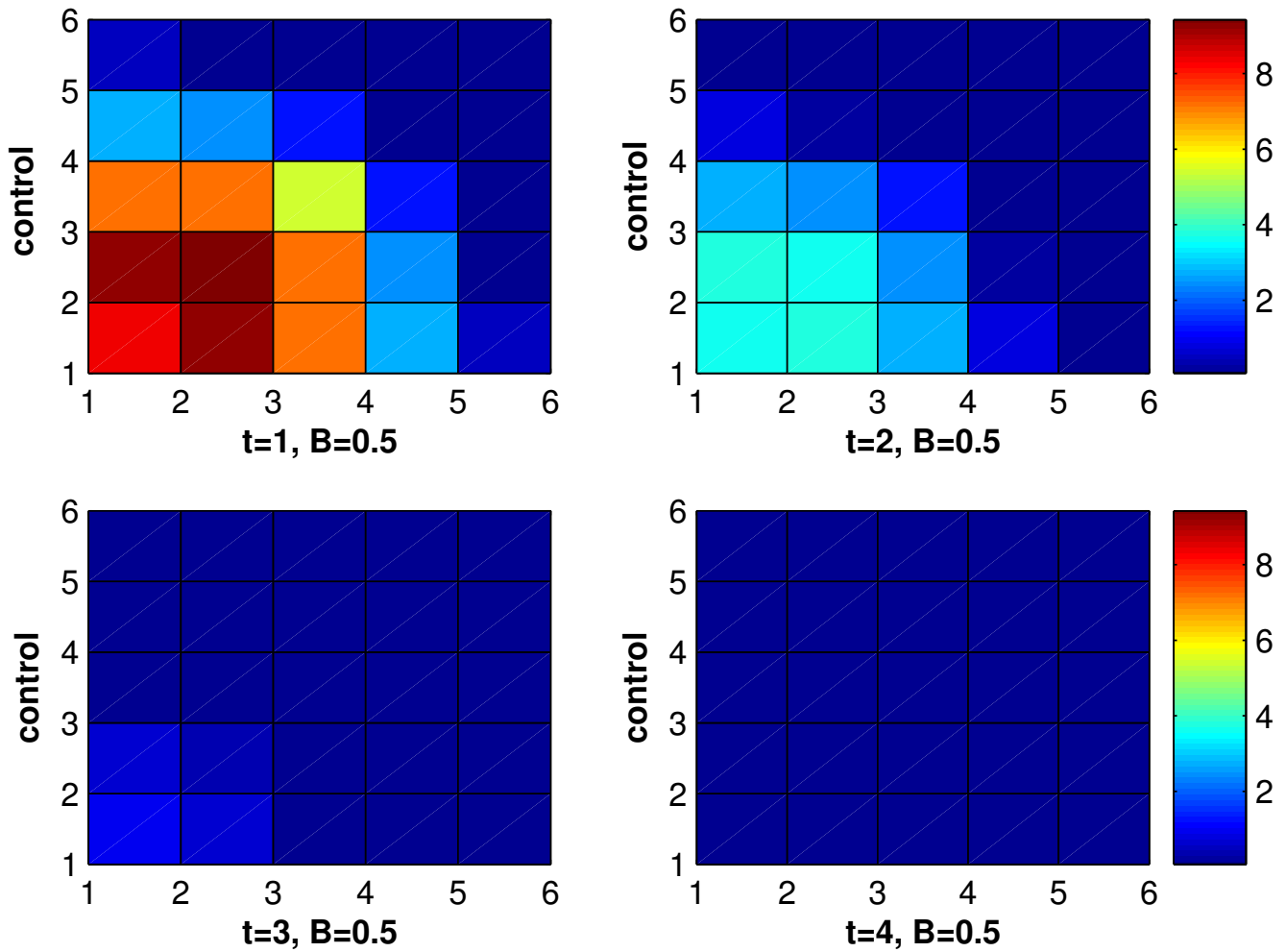
Infecteds, with control



Immune, with control



Opt. Control -number of baits in each box at each time



More Realistic Features

Other cases in 5 by 5 grid model

Geographic features - like a river

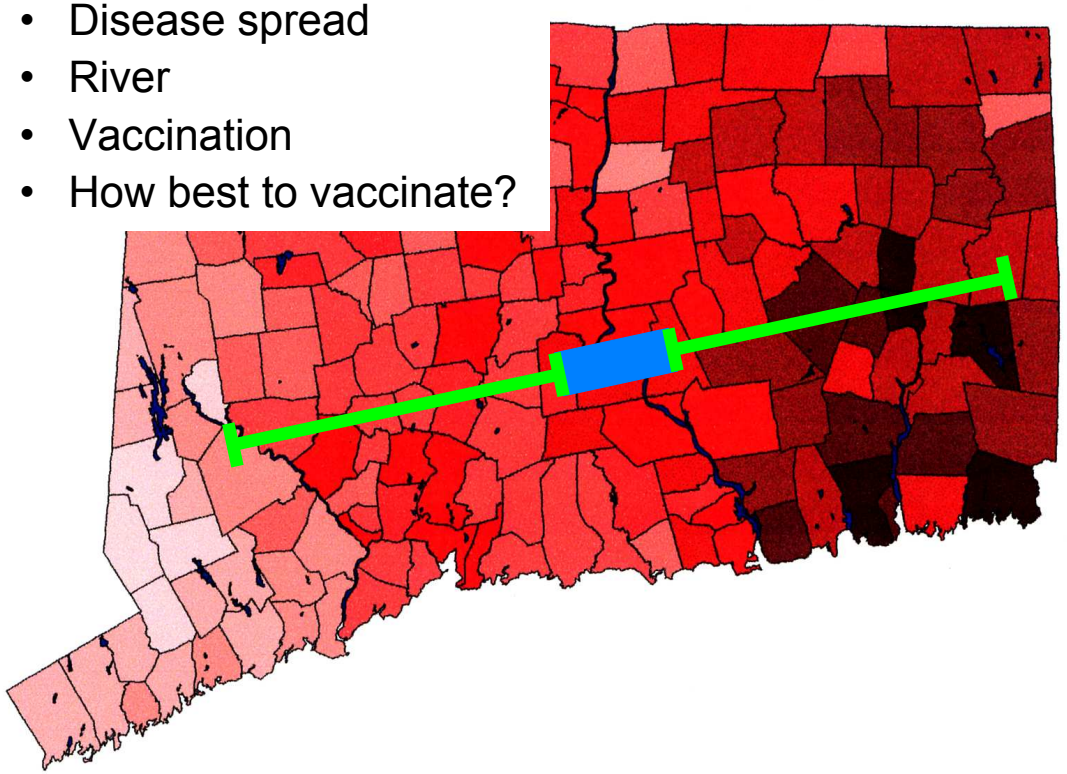
Birth pulses - disease outbreak in the spring

Models- discrete in time and space - and - systems of differential equations, with discrete space components

Connecticut River

Example

- Disease spread
- River
- Vaccination
- How best to vaccinate?



Conclude with a video

Show the actual data in video-format from rabies in foxes in Switzerland.

rabid foxes in red

vaccination areas in green

Publication (raccoon model): to appear in Journal of Biological Dynamics