

# MATH vs. RABIES

## USING MATHEMATICS TO HELP POLICY-MAKERS IN CONTROLLING CANINE RABIES IN DAVAO CITY

27<sup>TH</sup> MAY 2019



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COLLABORATORS

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City Veterinarian Office, City Health Office, and  
Davao Medical School Foundation





*Int. J. Data Analysis Techniques and Strategies, Vol. 2, No. 2, 2010*

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## **Rao DISC-based similarity coefficient: a measure of similarity with respect to feature differences**

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Mintal, Davao City 8000, Philippines

MY APPLIED MATH RESEARCH JOURNEY



- Chemical master equation of biochemical reaction system
- Image processing analysis and recognition of sign languages
- Sympatric speciation with symmetric bifurcation theory



**a place of mind**  
THE UNIVERSITY  
OF BRITISH COLUMBIA

# MY APPLIED MATH RESEARCH JOURNEY



ELSEVIER

## The Relative Contribution of Direct and Environmental Transmission Routes in Stochastic Avian Flu Epidemic Recurrence: An Approximate Analysis

May Anne Mata<sup>1,2</sup> · Priscilla Greenwood<sup>3</sup> · Rebecca Tyson<sup>1</sup>

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## A model for intracellular actin waves explored by nonlinear local perturbation analysis<sup>☆</sup>

May Anne Mata<sup>a,b</sup>, Meghan Dutot<sup>a</sup>, Leah Edelstein-Keshet<sup>a</sup>, William R. Holmes<sup>c,\*</sup>

<sup>a</sup> Department of Mathematics, University of British Columbia, Vancouver, BC, V6T 1Z2, Canada

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<sup>c</sup> Department of Mathematics, University of California, Irvine, CA 92697, United States

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Biophysical Journal Volume 108 January 2015 230–236

## Computational Tools

### Local Perturbation Analysis: A Computational Tool for Biophysical Reaction-Diffusion Models

William R. Holmes,<sup>1,2,\*</sup> May Anne Mata,<sup>3,4</sup> and Leah Edelstein-Keshet<sup>5</sup>

<sup>1</sup>Department of Mathematics, University of Melbourne, Parkville, Australia; <sup>2</sup>Center for Mathematical and Computational Biology, Center for ment of Mathematics, University of California Irvine, Irvine, California; <sup>3</sup>I. K. Barber School of Arts and bia Okanagan, Kelowna, British Columbia, Canada; <sup>4</sup>Department of Math, Physics, and Computer i Mindanao, Davao City, Philippines; and <sup>5</sup>Department of Mathematics, University of British Columbia,

[here to view linked References](#)

Journal of Mathematical Biology manuscript No.  
(will be inserted by the editor)

- 1 Random fluctuations around a stable limit cycle in a stochastic system with parametric forcing

3 May Anne Mata · Rebecca C. Tyson · Priscilla Greenwood

4

5 Date Submitted: February 26, 2019



## INTERNATIONAL WORKSHOP IN MATHEMATICAL BIOLOGY

# Synoptic study on Transmission

## and Optimum control to Prevent Rabies



**STOP RABIES**



# THE MATALAB'S RABIES MODELLING TEAM



**Eliezer Diamante**  
*Project Staff*



**Zython Paul Lachica**  
*Research Assistant*



**Sherelyn Evangelio**  
*Project Staff*



**Cherryl Prudenciado**  
ANALYSIS OF A RABIES MODEL FOR  
DOG POPULATION WITH  
VACCINATION



**Mae Leonacor Sibla**  
ANALYSIS OF A MODEL FOR RABIES IN  
STRAY DOG POPULATION WITH TWO  
TRANSMISSION ROUTES

# THE MATALAB'S RABIES MODELLING TEAM



**Xyza Mae Arandela**  
MODELING RABIES  
TRANSMISSION DYNAMICS  
AND CONTROL IN THE  
THREE ADMINISTRATIVE  
DISTRICTS OF DAVAO CITY



**Pamela Grace Roxas**  
OPTIMAL CONTROL  
THEORY APPLIED TO A  
RABIES EPIDEMIC  
MODEL WITH  
VACCINATION



**Novelyn Herrada**  
COST OPTIMIZATION  
OF INTERVENTION  
STRATEGIES TO  
ERADICATE RABIES IN  
DAVAO CITY USING  
LINEAR PROGRAMMING



**Rea Theresa Dapar**  
A MODEL FOR RABIES  
TRANSMISSION IN  
HUMANS WITH PRE- AND  
POST-EXPOSURE  
VACCINATION



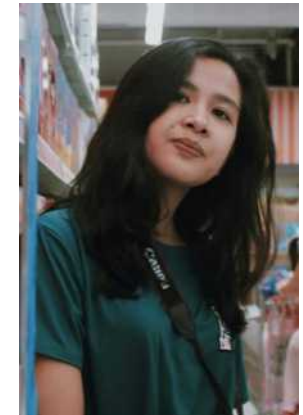
**Johanna Marie Peralta**  
TEMPORAL PATTERNS  
OF DOG RABIES IN  
DAVAO CITY BETWEEN  
YEARS 2006-2017



**Abigail Clemente**  
SPATIAL REGRESSION  
ANALYSIS ON REPORTED  
CANINE RABIES CASES IN  
DAVAO CITY, PHILIPPINES  
FROM 2006 TO 2017



**Abel Leandro Paras**  
AGENT-BASED  
MODELLING ON THE  
EFFECT OF DOG  
MOBILITY ON POSITIVE  
RABIES CASES



**Dejell Anne Satur**  
RISK FACTOR ANALYSIS  
FOR DOG BITE VICTIMS  
IN DAVAO CITY



# RABIES MODELLING TEAM

## @ DAVAO CHRISTIAN HIGH SCHOOL

- Rabies: A Dog's Biological Sex's Role in an Epidemic Model
- The Role Of Pet Ownership And Adoption On The Spread Of Rabies Virus Among Stray And Pet Dogs: An LHS-PRCC Sensitivity Analysis
- Dynamics of Rabies Epidemics With Unclean Environment: Understanding the Role of Direct and Indirect Transmission Rates Using the SEIR-V Epidemiological Model
- Detecting Serial Dependence On The Monthly Rabies Cases: An Application Of Generalized Linear Autoregressive Moving Average Framework
- Measuring The Effects Of Government-initiated Interventions, Dog Characteristics And Weather Conditions To The Rabies Cases From 2006 To 2018 In Davao City, Philippines



# RABIES

## RABIES

It is a zoonotic disease caused by RNA viruses of the *Lyssavirus* genus of *Rhabdoviridae* family that affects all mammals.

## RABIES IN THE WORLD

Estimated to cause about 60,000 deaths annually (OIE, 2017)

99% of which is caused by dog bites (WHO, 2017)

95% of the human rabies cases occurs in Asia and Africa (WHO, 2017)

## RABIES IN THE PHILIPPINES

Estimated to cause the death of about 200-300 Filipinos annually (DOH, 2017)

Dogs remain to be its principal carrier

Affects communities with limited knowledge about the disease (Dimaano et al., 2011)

# CALL TO ERADICATE RABIES BY 2020!



<https://goo.gl/images/ckzZPo>



<https://goo.gl/images/6fpUEd>

### Be a Responsible Dog Owner

- Don't allow your dog to stray in public areas.
- Vaccinate dogs against rabies at the age of three months and every year thereafter.
- Take care of your pets by giving regular baths, adequate food and clean water, and providing clean quarters.

### What to do if bitten by a dog

1. Immediately wash with running water and soap.
2. Consult immediately with the nearest health center.
3. Observe the dog for 14 days if there are any changes in its behavior.
4. If you see a roaming mad dog, immediately report to police or barangay officials in your locality.

### What is Rabies?

• Rabies is a highly fatal disease. It is due to the virus that can be found in the saliva of an animal infected with virus.  
 Rabies can be transferred to humans by way of a bite from an animal infected with rabies, like a dog or a lick from a dog infected with rabies.

### Symptoms of dogs with rabies

1. Dog becomes vicious.
2. Dog runs aimless.
3. Biting of any objects.
4. Profuse salivation.
5. Does not drink or eat.

**Animal Bite Treatment Center**

No.	Name	Address
1.	Bala Provincial Hospital	529-7448, 529-7425 Poblete, Bala
2.	Passi City Health Unit	311-5044 Passi City, Bala
3.	Don Valerio Palmares Sr. Memorial District Hospital	311-5493, 367-1441 Passi City, Bala
4.	Ray, Pedro Inno Memorial District Hospital	612-0234, 195-5931 Dumalag, Bala
5.	Sara District Hospital	292-0144, 292-0201 Sara, Bala
6.	Dr. Ricardo Y. Ladrado Memorial District Hospital	533-7266, 349-1576 Lambunan, Bala
7.	Ramon Tabana Memorial District Hospital	522-4911, 522-4847 Calapanan, Bala
8.	Federico Roman Trindler Sr. Memorial District Hospital	173-1191, 619-4924 Jempang, Bala
9.	Jesus Colanaran District Hospital	397-0286, 397-0879 Balsuran, Bala
10.	Barotac Vieja District Hospital	342-0186, 342-0300 Blac, Yaya, Bala
11.	Bala Provincial Capital	608-4915 Bala City

Let us prevent rabies. Be a responsible dog owner.  
 For further information Please call or write:

**Provincial Veterinary Office (P.V.O.)**  
 5th Floor, New Provincial Capitol, Iloilo City  
 Tel. # 3372193/5095084

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**Korea International Cooperation Agency (KOICA)**  
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Arise, shine, for your light has come and the glory of the LORD rises upon you! Isaiah 60:1

<https://goo.gl/images/mVsCcn> 11

# RABIES THRIVES STILL, IT KILLS!!!

BBC

Sign in

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Reel

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More

## NEWS

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## Norwegian woman dies from rabies after Philippines puppy bite

11 May 2019



Share

**A Norwegian woman has died after contracting rabies from a stray puppy in the Philippines.**

Birgitte Kallestad, 24, was on holiday with friends when they found the puppy on a street, her family said in a statement.

The puppy is thought to have infected her when it bit her after they took it back to their resort.

She fell ill soon after returning to Norway, and died on Monday at the hospital where she worked.

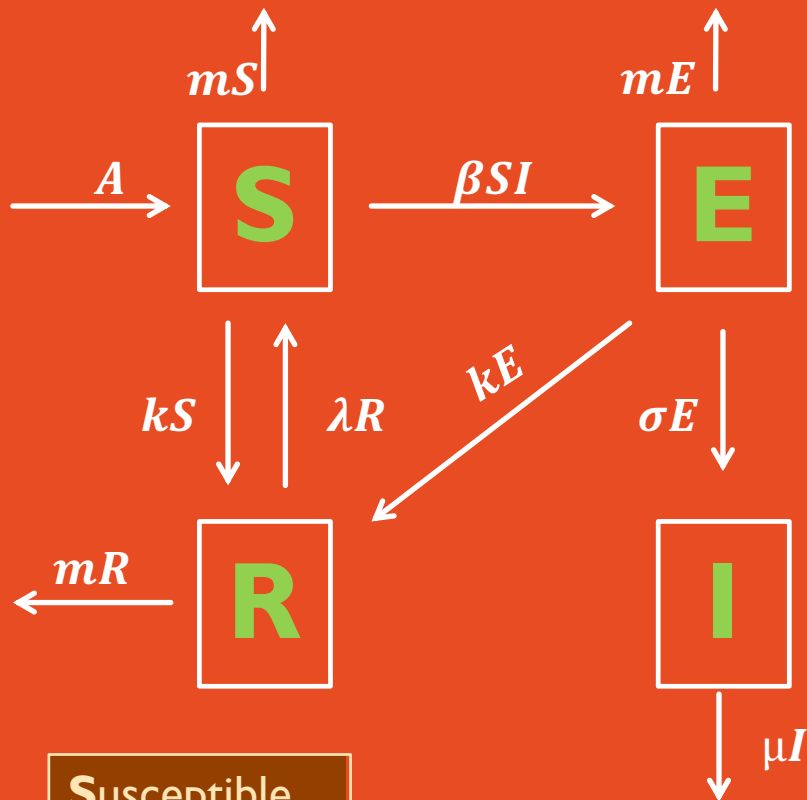
It is the first rabies-related death in Norway for more than 200 years.

# MATH vs RABIES

## Round I



IS RABIES-FREE PHILIPPINES BY 2020 ACHIEVABLE?



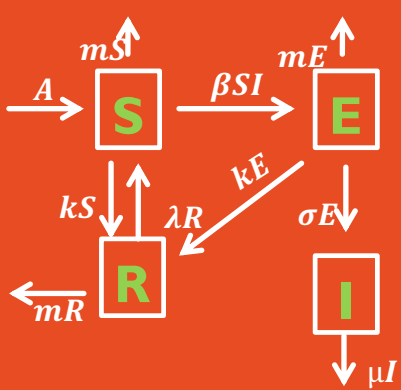
Susceptible  
Exposed  
Infectious  
Recovered

Parameters	Value	Description	Source
<b>A</b>	0 up to 2M	annual crop of dogs	assumption
<b>m</b>	0.08	natural mortality	Zhang et al. (2011)
<b><math>\mu</math></b>	1	rabid dog mortality rate	Zhang et al. (2011)
<b><math>\beta</math></b>	0 to 1	transmission rate	assumption
<b>k</b>	0 to 1	vaccination rate	assumption
<b><math>\sigma</math></b>	1/6	incubation period	Zhang et al. (2011)
<b><math>\lambda</math></b>	0.3, 0.4, 0.5, 1	loss rate of vaccination immunity	assumption

# MATH vs RABIES

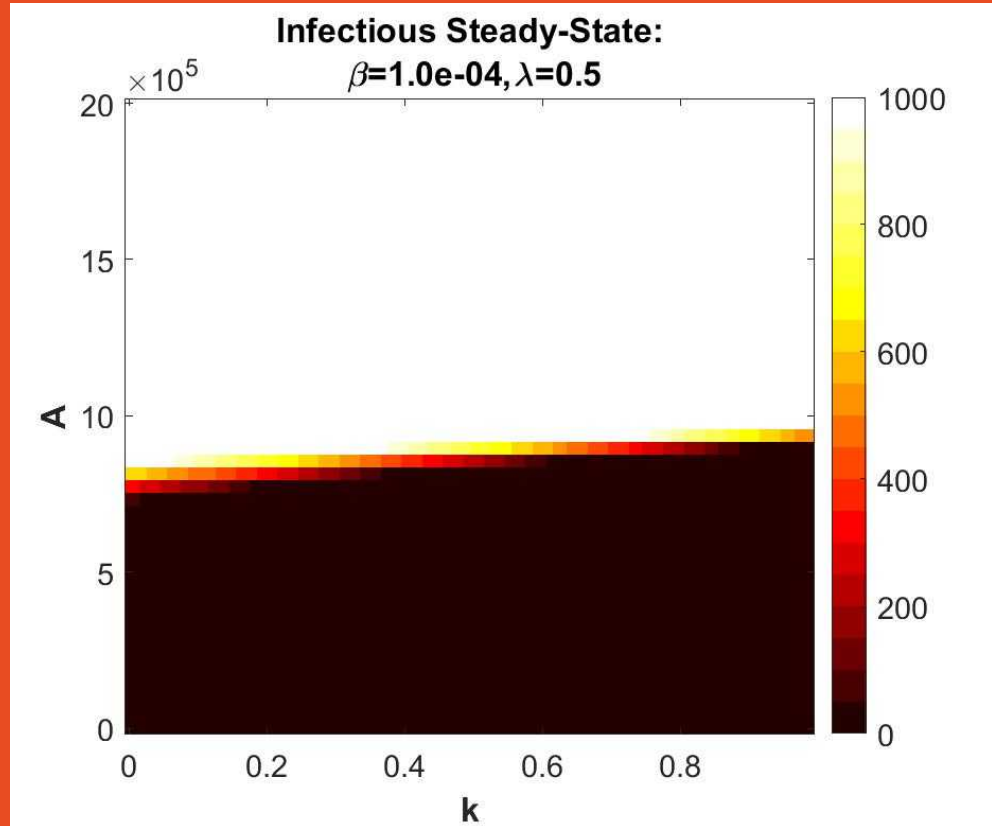
## Round I

IS RABIES-FREE PHILIPPINES BY 2020 ACHIEVABLE?



$$I^*(A, k, \lambda, \beta) = \frac{\mu(\sigma + m + k)[(m + k)(\lambda + m) - k\lambda] - A\beta\sigma(\lambda + m)}{\beta\mu[k\lambda - (\sigma + m + k)(\lambda + m)]}$$

$$\begin{aligned} \frac{dS}{dt} &= A + \lambda R - S(k + m) - \beta SI \\ \frac{dE}{dt} &= \beta SI - E(m + \sigma + k) \\ \frac{dI}{dt} &= \sigma E - \mu I \\ \frac{dR}{dt} &= k(E + S) - R(\lambda + m) \end{aligned}$$



If the annual crop of dog falls below ~500,000 per year, then it is always possible..

# MATH vs RABIES

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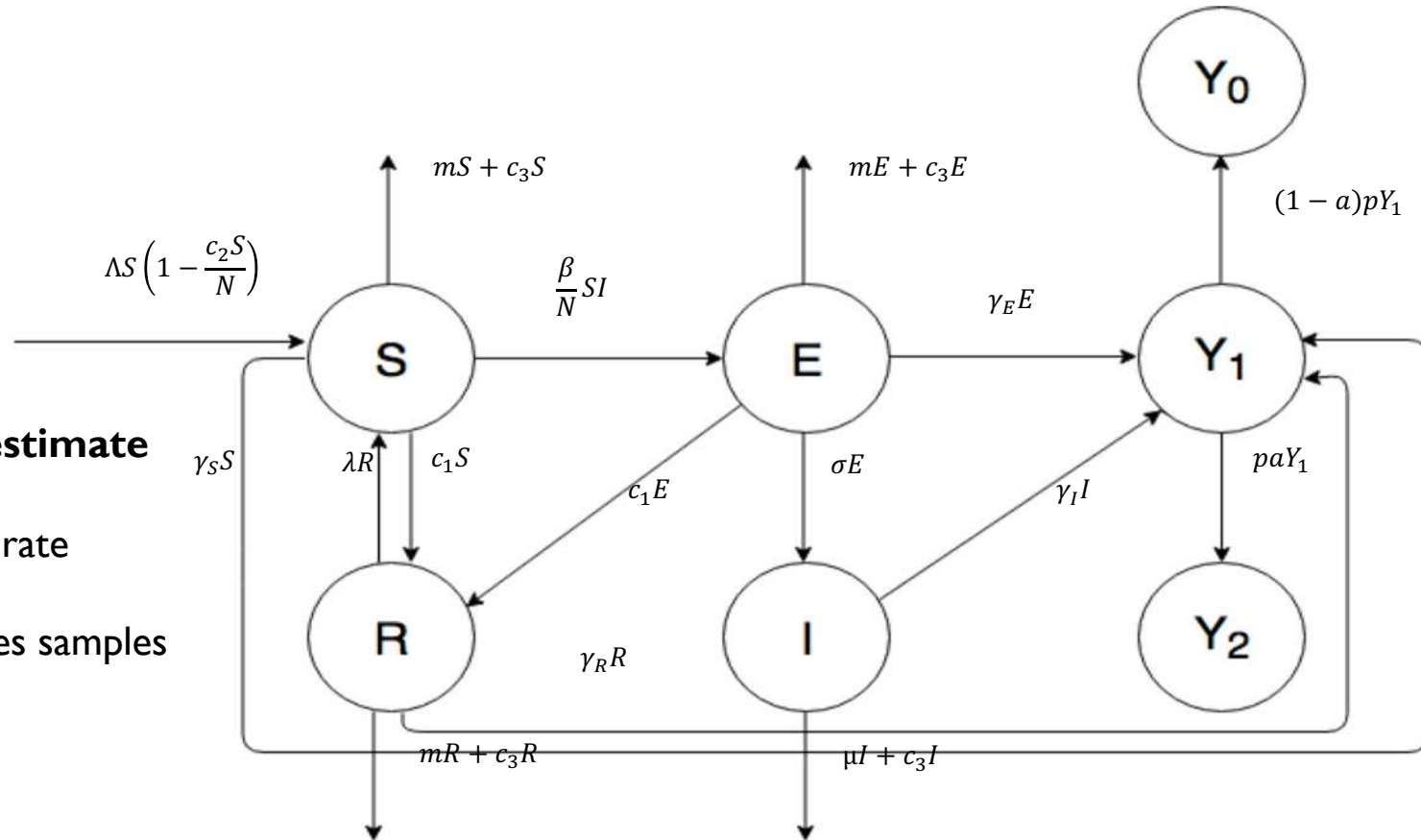
## Round 2

ARE THE EFFORTS BEING DONE ENOUGH?

# MATH vs RABIES

## Round 2

### WHAT ARE THE EFFORTS THAT HAVE BEEN DONE SO FAR?



### II parameters to estimate

- Birth (per capita) rate
- Transmission rate
- % of positive rabies samples
- Vaccination rate
- Castration rate
- Impounding rate
- Examination rate
- Reporting rate of susceptible
- Reporting rate of exposed
- Reporting rate of infectious
- Reporting rate of recovered dogs

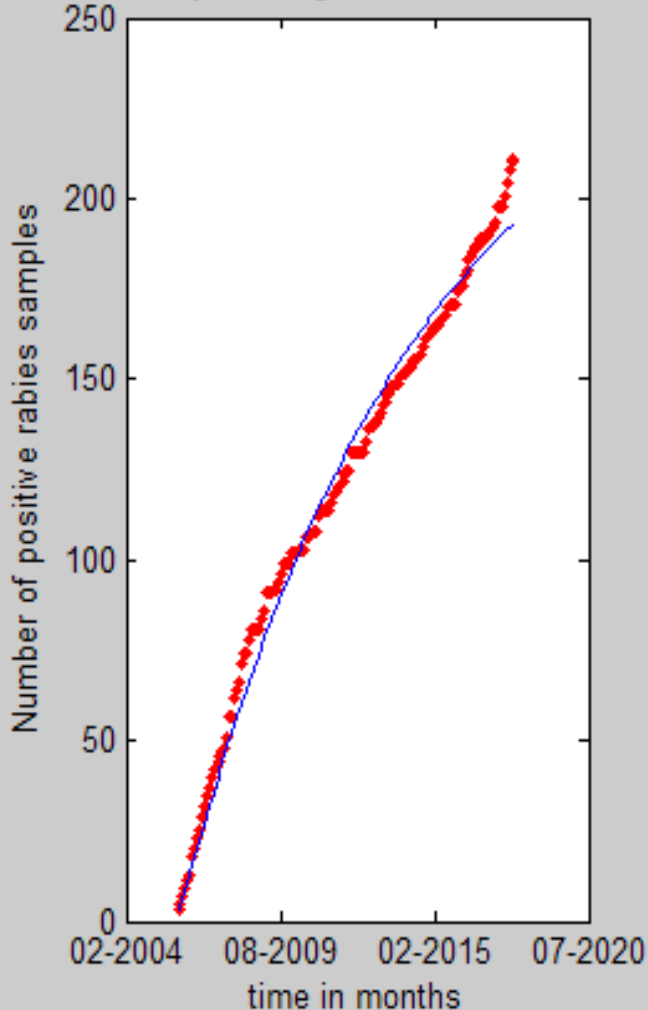


# MATH vs RABIES

## Round 2

### WHAT ARE THE EFFORTS DONE SO FAR?

Davao City fit using estimated parameters



Parameter	Estimates
Per capita birth rate	0.3165
Transmission rate	$3.08 \times 10^{-8}$
% of positive rabies samples	$2.72 \times 10^{-5}$
<b>Vaccination rate (per mo.)</b>	<b>0.1957</b>
<b>Castration rate (per mo.)</b>	<b>0.0155</b>
<b>Impounding rate (per mo.)</b>	<b>0.0208</b>
Examination rate	0.0236
Reporting rate of susceptible	0.1071
Reporting rate of exposed	0.3947
Reporting rate of infectious	0.7011
Reporting rate of recovered	0.2994

# MATH vs RABIES

## Round 2

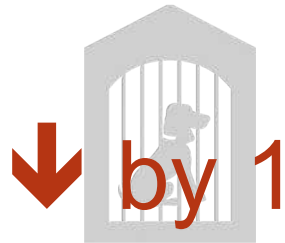
ARE THESE EFFORTS STATISTICALLY SIGNIFICANT?



when cases  
include stray dogs  
aside from owned



per 1mm rise in  
precipitation



per 1250  
impounded dogs



when >1 district  
has cases

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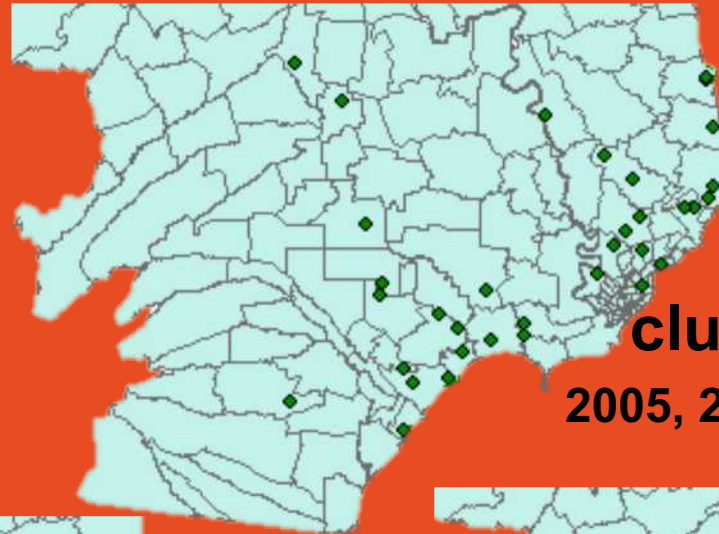
stat. insignificant drivers:

vaccination • castration • IEC • temperature • humidity

# MATH vs RABIES

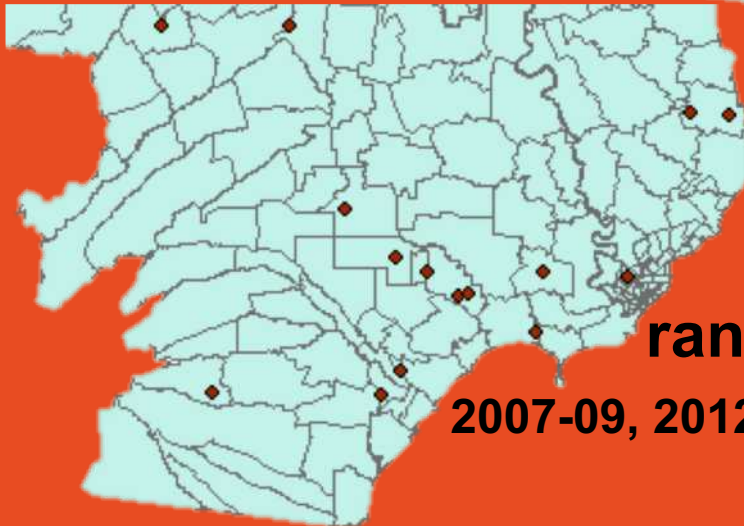
## Round 3

DOES THE SPATIAL DISTRIBUTION OF RABIES CASES GIVE CLUE?



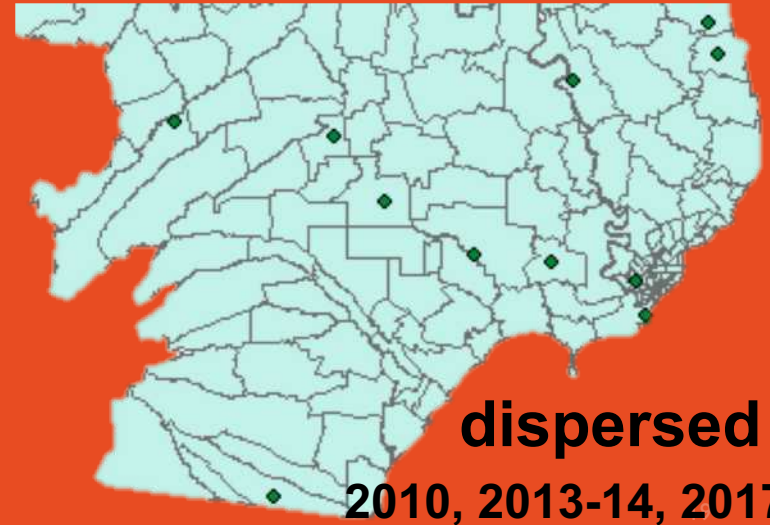
**clustered**

**2005, 2006, 2011**



**random**

**2007-09, 2012, 2015-16**



**dispersed**

**2010, 2013-14, 2017**

# MATH vs RABIES

## Round 3

DOES THE SPATIAL DISTRIBUTION OF RABIES CASES GIVE CLUE?

Null Hypothesis: There is no spatial auto-correlation.

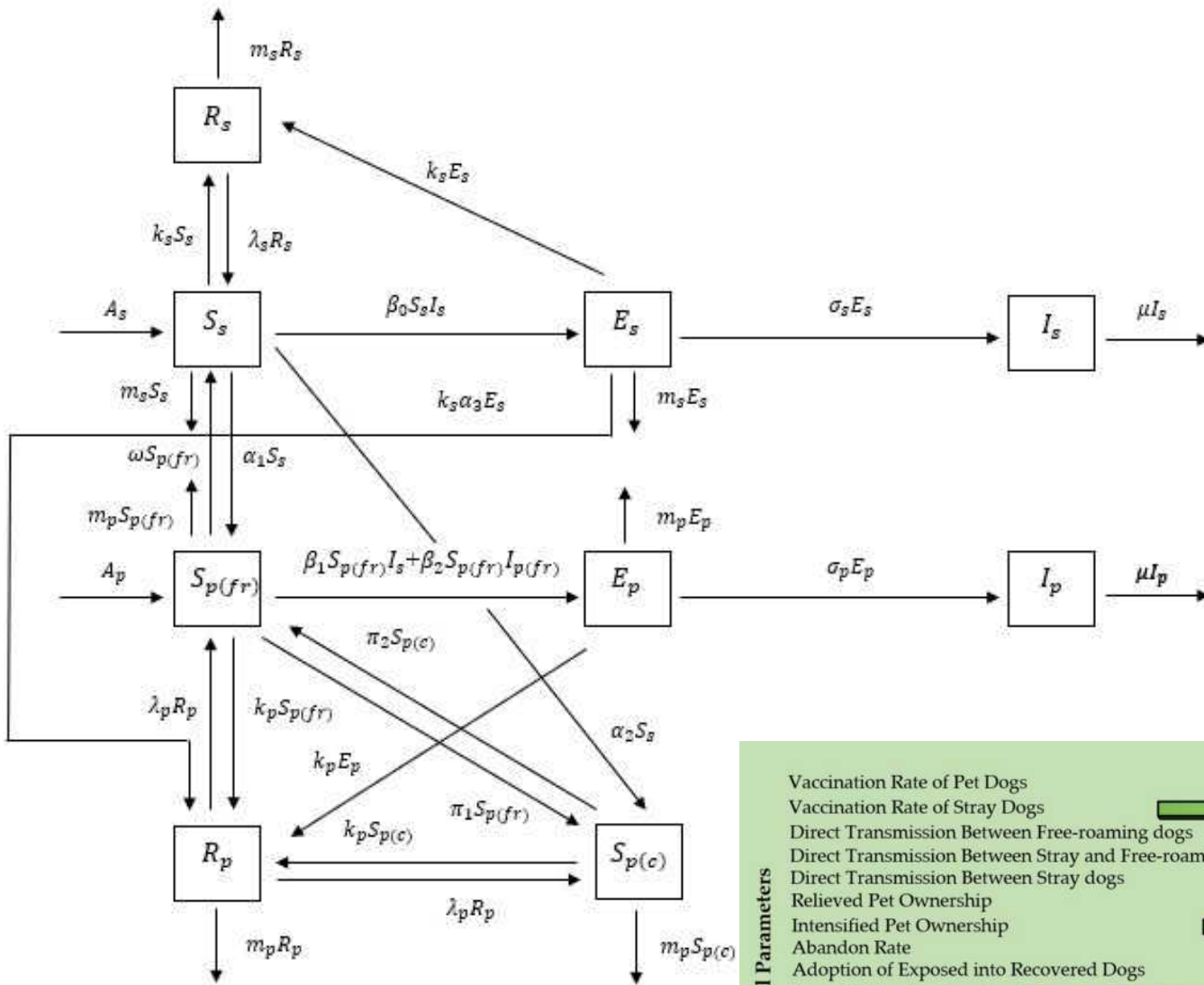
Spatial autocorrelation	Queen's Contiguity	1-Nearest Neighbor	2-Nearest Neighbor	3-Nearest Neighbor
p-value	0.23	0.51	0.27	0.63

Conclusion: The number of rabies cases we observe in one district does not predict the number of rabies cases in the neighborhood

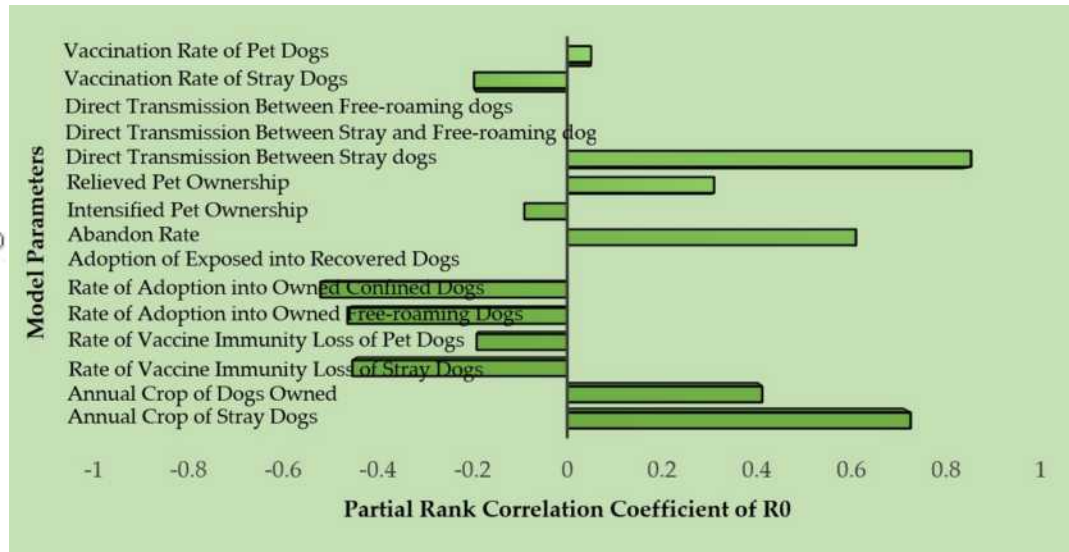
**SPACE (at a district level) does not matter!**

## WHAT HAVE WE LEARNED SO FAR?

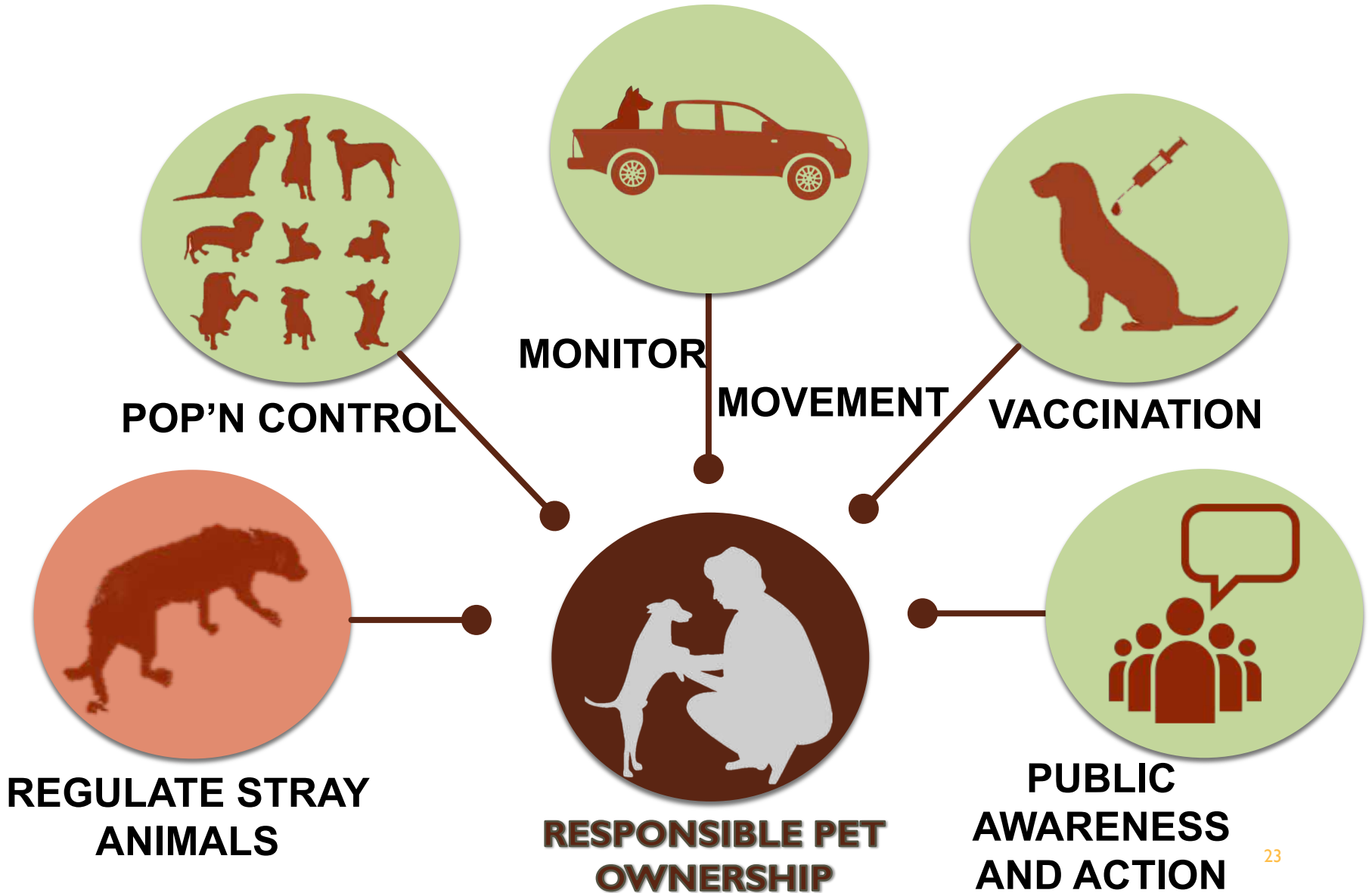
- Rabies-free Philippines by 2020 is achievable if we keep the annual crop of dogs as low as possible → dog population control
- Intervention efforts must be strengthened: vaccination is not enough
- No spatial pattern of rabies cases at a district level



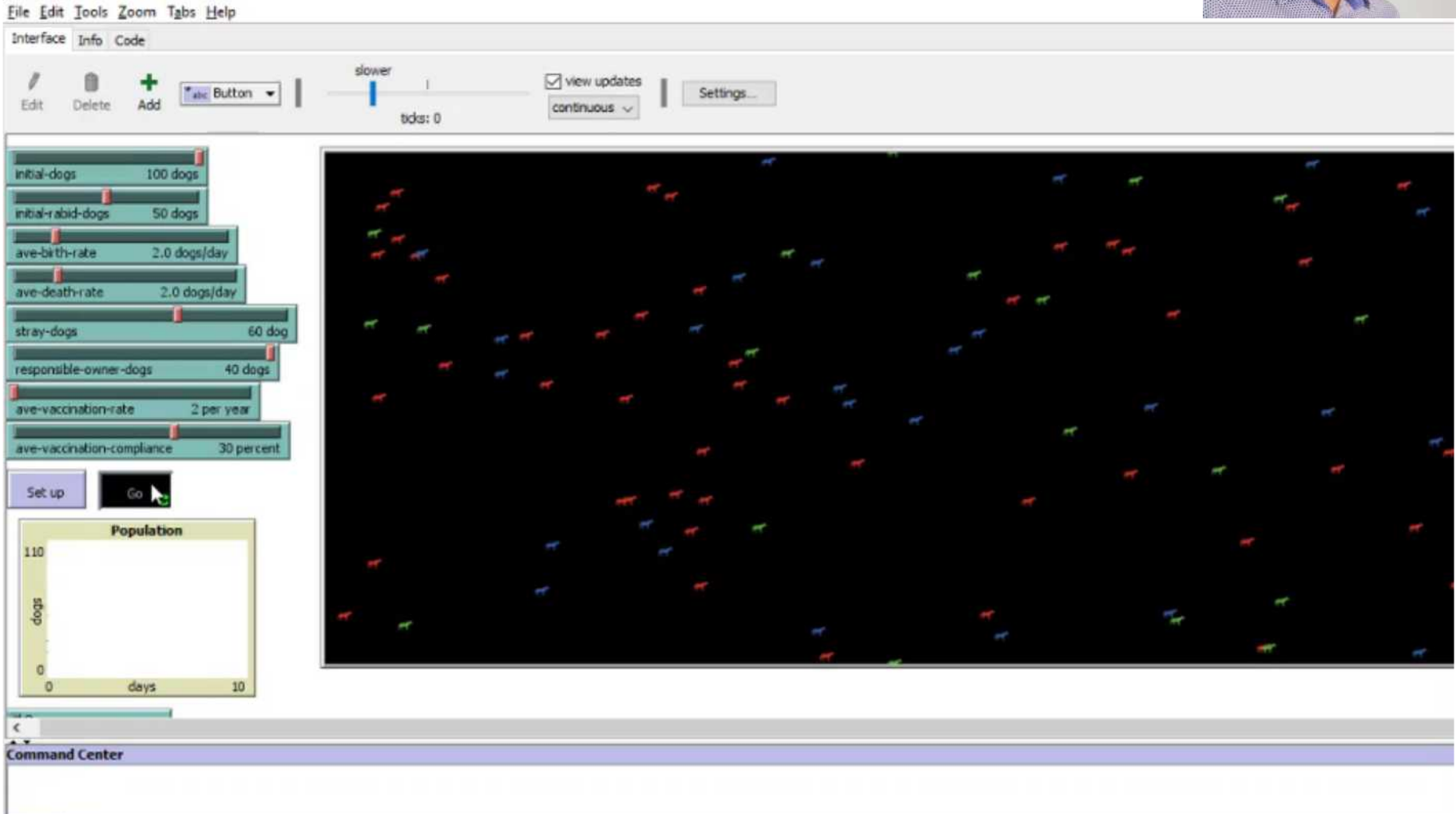
# WHAT ABOUT RESPONSIBLE PET OWNERSHIP?



# WHAT POLICY-MAKERS SHOULD DO?



# 40% RESPONSIBLE DOG-OWNERS 30% AVE.VACCINATION COMPLIANCE





# JUST 75% RESPONSIBLE DOG-OWNERS



File Edit Tools Zoom Tabs Help

Interface Info Code

Edit Delete Add  | slower |  view updates | Settings... | continuous

ticks: 0

initial-dogs 100 dogs  
initial-rabid-dogs 50 dogs  
ave-birth-rate 2.0 dogs/day  
ave-death-rate 2.0 dogs/day  
stray-dogs 25 dog  
responsible-owner-dogs 75 dogs  
ave-vaccination-rate 0 per year  
ave-vaccination-compliance 0 per cent

Set up Go

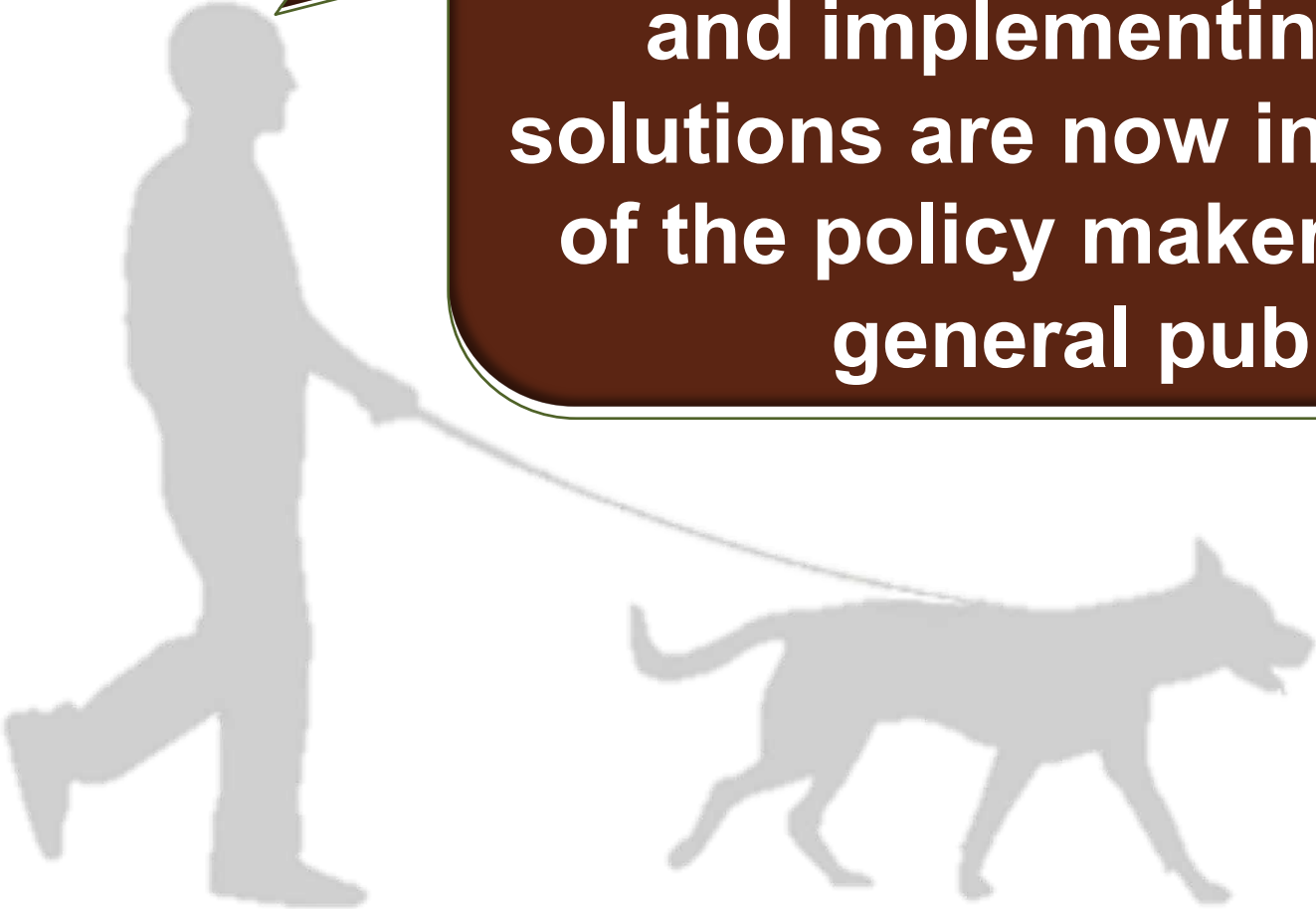

Population

dogs  
0 110  
0 days 10

Command Center

observer >

The image shows a software interface for a simulation. On the left, there is a list of parameters with sliders and numerical values. Below this is a 'Population' graph with a y-axis labeled 'dogs' (0 to 110) and an x-axis labeled 'days' (0 to 10). The main area is a large black rectangle containing many small dog icons, some red and some green, scattered across the field. At the bottom, there is a 'Command Center' area with a prompt 'observer >'.



**Science and math have the tools to provide answers in controlling rabies, but crafting and implementing these solutions are now in the hands of the policy makers and the general public.**

# DaghangSalamat!

## CONTACT INFORMATION

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